NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Managing Safety on Passenger Railroads: Amtrak Overspeed Derailment – DuPont, Washington; and CSX and Amtrak Train Collision – Cayce, South Carolina.

GROUP	B
EXHIBIT	
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Agency / Organization

NTSB

Title

Crashworthiness and Survival Factors Group Factual Report- DuPont, WA

Docket ID: **DCA18HR001**

National Transportation Safety Board

Office of Railroad, Pipeline and Hazardous Materials Investigations

Washington, DC 20594

Amtrak Passenger Train 501 Derailment
DuPont, Washington
December 18, 2017

RRD18MR001

Crashworthiness and Survival Factors

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Abbreviations and Acronyms

AAR	Association of American Railroads
AC	Alternating current
ADA	American Disabilities Act
BLET	Brotherhood of Locomotive Engineers and Trainmen
CA	California
CALTRANS	California Department of Transportation
CEM	Crash energy management
CFR	Code of Federal Regulations
ELD	Electronic logging device
EPA	Environmental Protection Agency
FBI	Federal Bureau of Investigation
FR	Federal Register
FRA	Federal Railroad Administration
GE	General Electric
HEP	Head end power
IDOT	Illinois Department of Transportation
JBLM	Joint Base Lewis McCord
KY	Kentucky
LCR	Locomotive cab radio
LDVR	Locomotive digital video recorder
MP	Mile post
MP&E	Motive Power and Equipment
Mph	Miles per hour
NRC	National Response Center
NTSB	National Transportation Safety Board
NV	Nevada
PA	Pennsylvania
POD	Point of Derailment
PST	Pacific Standard Time
RPO	Railway Post Office
SC	South Carolina
TOD	Train operator’s display
UIC	International Union of Railways
US	United States
USCG	United States Coast Guard
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol

1 Factual Information

1.1 Accident Reference Information

NTSB Accident Number:	RRD18MR001
Location of Accident:	DuPont, Washington
Date of Accident:	December 18, 2017
Time of Accident:	7:33 a.m. (PST)[1]
NRC Report No.:	1199927[2]
Type of Incident:	Derailment
Railroad Property:	State of Washington
Track Location:	Lakewood Subdivision, milepost (MP) 19.86
Train:	Amtrak 501
Owner:	
Lead Locomotive:	Washington Department of Transportation
Trailing Locomotive:	Amtrak
Passenger Cars:	Washington Department of Transportation
Train Type:	Passenger
Consist:	Lead locomotive, 12 passenger cars, trailing locomotive
Weight:	690,000 lbs.
Length:	659-feet
Operating Direction:	Southbound
Equipment Manufacturer:	
Lead Locomotive:	Siemens
Passenger Cars:	Talgo, Inc.
Trailing Locomotive:	General Electric
Train Operator:	Amtrak
Injuries:	74
Fatalities:	3

[1] All times referenced in this report are *Pacific Standard Time*.
[2] National Response Center, a function of United States Coast Guard, provides initial notification to specific US Department of Transportation / Federal Railroad Administration (USDOT / FRA) and NTSB offices, of transportation related incidents that meet certain pre-established criteria. See http://www.nrc.uscg.mil for report.

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1.3 Accident Synopsis

For a description of the accident see the *Accident Synopsis* located in NTSB docket RRD18MR001.

1.4 Derailment Sequence

On December 18, 2017, Amtrak's "Mt. Adams" Train No. 501, was traveling southbound on the Lakewood subdivision in DuPont, Washington, which is a railroad corridor that has been upgraded in three separate phases by Sound Transit and the Washington State Department of Transportation (WSDOT). Amtrak train 501 consisting of 14-vehicles – a Siemens's Charger locomotive in the lead, a Talgo Series IV trainset of 12 semi-permanently coupled cars, and a GE P-42 locomotive in the rear, derailed on its entry into the curve at MP 19.86 immediately before a bridge that passed over the lanes of southbound Interstate 5 in DuPont, Washington.[3] Event recorder data showed the train was traveling at about 80 miles per hour (mph) when it derailed. Figure 1 shows a post-derailment schematic of the train illustrating the resting location and orientation of the locomotive and cars, and the locations of the detached and partially detached rolling assemblies.

This section of the report examines the kinematics involved in this accident based on investigators examination of the resting positions of the equipment, physical damages imparted into each car, physical damages imparted into the surrounding area and statements from witnesses who were directly involved in this accident.

[3] A *Semi-permanently* trainset is one in which cars are coupled through an articulated connection. This connection cannot be traditionally uncoupled like traditional North American mechanical couplers. The trainset is retained in its configuration unless special tools are used by qualified mechanics in a facility.

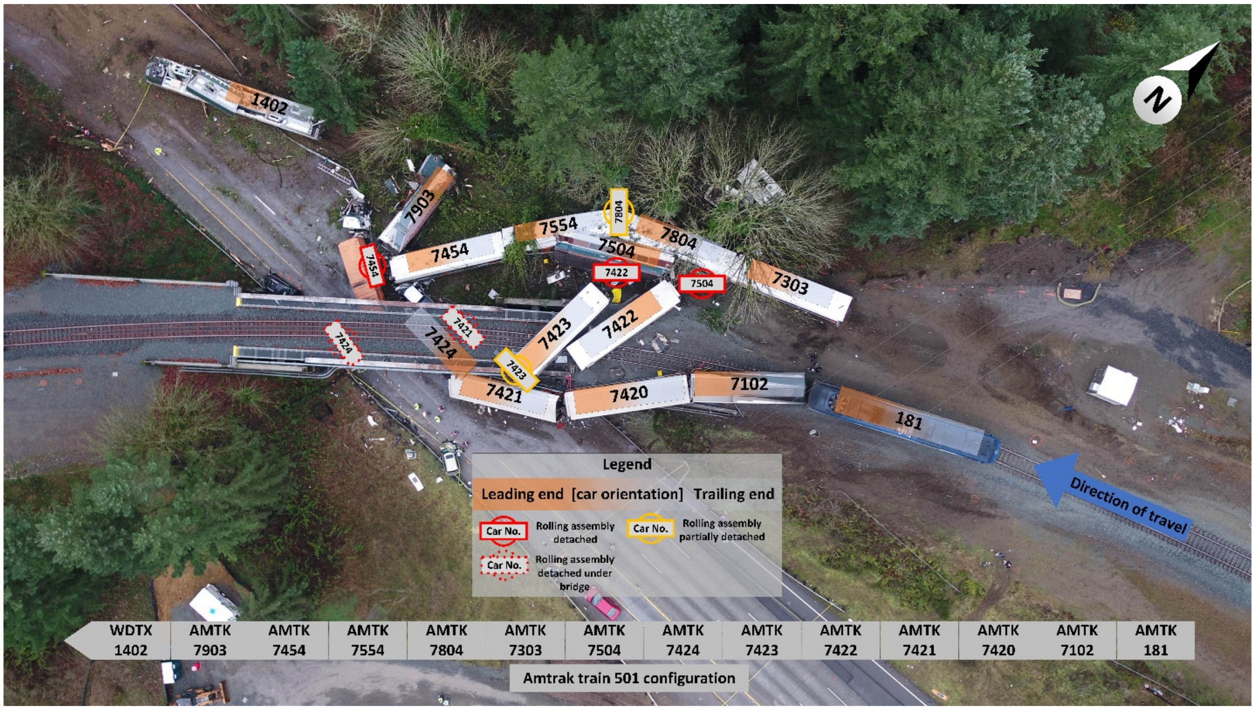


Figure 1. Post derailment schematic of train 501. (Photo WSP)

1.4.1 Derailment Kinematics

The following section describes the estimated kinematics of Amtrak Train No. 501, based upon the known initial position and velocity of train 501, the evidence of interactions between each vehicle and the wayside structures, and the known final positions of the cars.

The locomotive derailed on the high side of the curve to the right and traveled through the ballast, down the embankment through a wooded area and came to rest at about highway mile marker 116.6 on the southbound lanes of Interstate 5, upright in the original direction of travel however the damage exhibited on the right side of the locomotive was consistent with it being on its side at some point during the derailment. This is discussed further in section 1.5.1.4. Wheel and wheel flange markings identified on the track at MP 19.86 indicate the train's point of derailment (POD). Imprints cut into the wooden ties to the right of the track and disturbed ballast show the subsequent trajectory of the lead (WDTX 1402) locomotive's wheels traveling approximately west-southwest.

The lead locomotive detached from the power car, AMTK 7903. The power car and passenger cars, AMTK 7454, 7554, 7804, 7303, followed a similar trajectory as the lead locomotive into the wooded area. AMTK 7903 came to rest partially on the interstate, rotated clockwise about 90° from its original direction of travel and onto its left side. Passenger cars AMTK 7454, 7554, 7804 and 7303 remained coupled and upright. Passenger car AMTK 7504 rotated 180° from its original direction of travel and came to rest with its rear left side on top of the AMTK 7554 and its front left side leaning against AMTK 7804.

AMTK 7424 traversed along the east (left) side of the track down the embankment and onto the highway coming to rest under the bridge overpass on its roof with its lead end facing north. AMTK 7423 and 7422 came to rest on the bridge oriented laterally across the track. AMTK 7423 was rotated approximately 50° counterclockwise to the track. AMTK 7422 rotated about 120° clockwise to the track with the leading end of the car's left corner extending over the embankment.

A total of six articulated connections, the principle connections responsible for connecting the Talgo cars together, failed. (This will be examined later in this report) Five rolling assemblies from the Talgo passenger cars fully detached during the derailment and one partially detached. One of the fully detached rolling assemblies was involved in a raking collision with passenger car, AMTK 7504, where three passengers were killed. (This will be examined later in this report.)

Rolling assemblies are located at the leading end (oriented relative to the direction of travel) of the 12-semi-permanently coupled cars. The rolling assembly from AMTK 7424 was located underneath the bridge next to the left guardrail on the south lanes of Interstate 5. The rolling assembly from AMTK 7421 was located behind a Ford pickup truck on the south lanes of Interstate 5. The specific details of each rolling assembly are described later in this report. (See figure 2.)

Figure 2. AMTK 7421 resting on AMTK 7424, detached rolling assemblies indicated. (Photo WSP)

1.4.1.1 Sequential Kinematic Interactions

Damage to the concrete wall to the right of the track and the signal post at the POD are consistent with the train colliding with these wayside structures.

Figure 3. Concrete wall adjacent to track near the POD.

Horizontal abrasions were evident along the right side of passenger cars AMTK 7804 and 7303 measuring between 13 inches to 30 inches above the car floor.[4] The lower section of the wall in the foreground of figure 3 measures 30-inches high and upper block measures 60-inches high.

As the lead locomotive and the first six passenger cars of the train then derailed to the right of the main track and down the embankment, the articulated connection between the sixth car, AMTK 7504 and the seventh car, AMTK 7424 fractured. AMTK 7504's articulated coupler connection with the fifth car, AMTK 7303, was also fractured.

[4] Section 1.5.3.3, Post Accident Observations and Inspection, of this report details the damages associated with AMTK 7303 and AMTK 7804.

The cars trailing behind AMTK 7504 then traveled to the left of the main track. In the aerial photograph below witness marks visible in the ballast and soil clearly show the path of travel of the train. See figure 4.

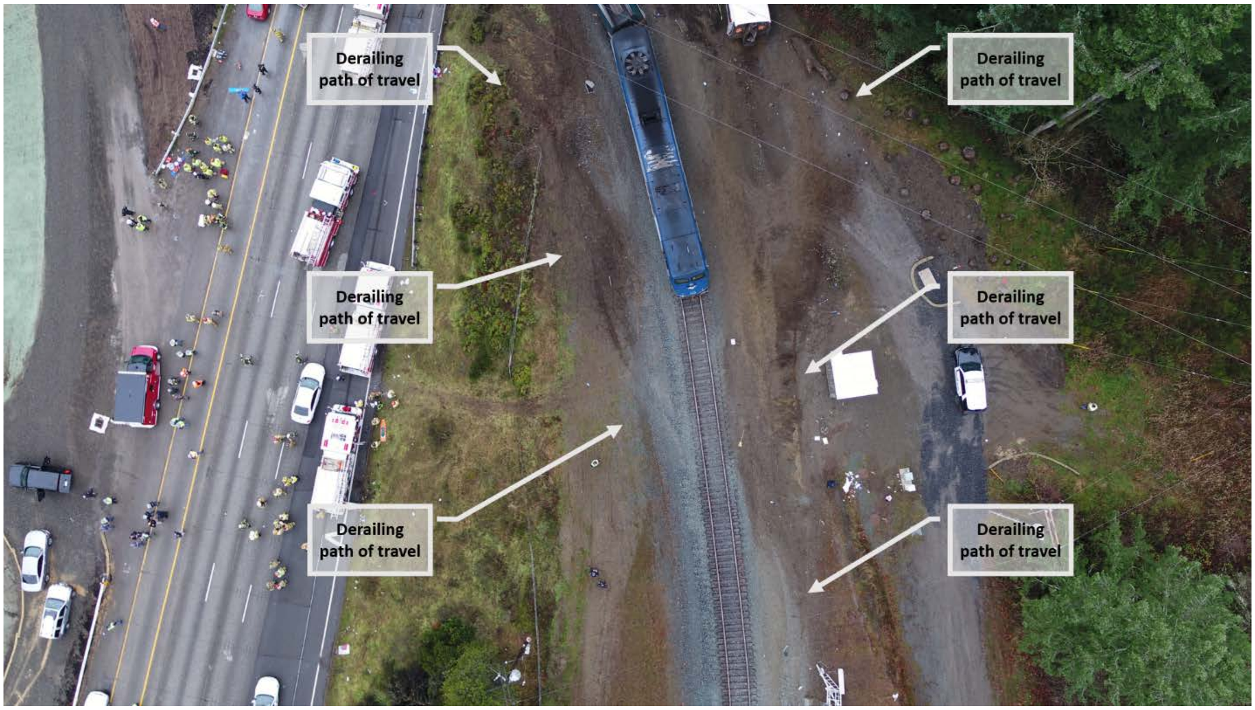


Figure 4. Derailing path of travel of Amtrak 501. (Photo WSP)

The lead locomotive, WDTX 1402, received impacts to the front top section of the cab. The cab roof deformed into the operator's compartment about 13-inches. The roof panels sheared off exposing the machine room compartments. The right side of locomotive exhibited horizontal scrape marks along its full length and mud, dirt, wood and rocks were lodged into the side panels, consistent with the locomotive proceeding through the woods on its side. The locomotive came to rest about 457-feet from the POD, on the interstate, upright and forward facing, indicating it righted itself as it moved through the wooded area impacting the adjacent trees and passing through the highway guardrail, which was located beneath the locomotive.

Figure 5. WDTX 1402 Post derailment position.

During interviews with highway vehicle operators, a driver of a white Toyota RAV4 said she was traveling southbound in the right lane when her vehicle was struck from behind by the locomotive. The vehicle came to rest on the left side of the roadway, facing north in the southbound lane.

Figure 6. Photograph of highway vehicle struck by lead locomotive. (Photo provided by driver.)

The power car, AMTK 7903, followed a similar trajectory as WDTX 1402 through the woods. It traveled about 341-feet from the POD. The mechanical coupler between the power car and the locomotive fractured. (The Talgo consist is equipped with a standard AAR “H” tightlock coupler at each end, to allow coupling to a locomotive at each end.) AMTK 7903 came to rest on its left side, rotated about 90° from its original direction of travel. AMTK 7903’s rear end structure abutted the front of AMTK 7454 (trailing car) and witness indications were consistent with a collision with the orange trailer of a tractor and semi-trailer (semi-truck) that was traveling southbound on Interstate 5.

AMTK 7454 followed a similar trajectory as AMTK 7903. The clockwise rotation of AMTK 7903 pushed AMTK 7454 in a counterclockwise rotation about 37° from its original direction of travel. It came to rest on the interstate about 314-feet from the POD. The articulated connection of AMTK 7454 and AMTK 7554 remained intact. Impact indications were observed between the end wall structure of AMTK 7554 and AMTK 7454. Further details of the articulated coupler connections can be found in section 1.5.3.3 of this report. The rolling assembly from AMTK 7454 separated from its attachments, however, the assembly remained near the supported end of this car.

Figure 7. Detached rolling assembly from AMTK 7454. (Photo WSP)

AMTK 7554 came to rest upright in the woods remaining coupled to and aligned with AMTK 7454. AMTK 7504, the sixth car, was positioned on its left side against the roof of AMTK 7554 and AMTK 7804. The damage of AMTK 7554's roof structure is associated with the impact from AMTK 7504.

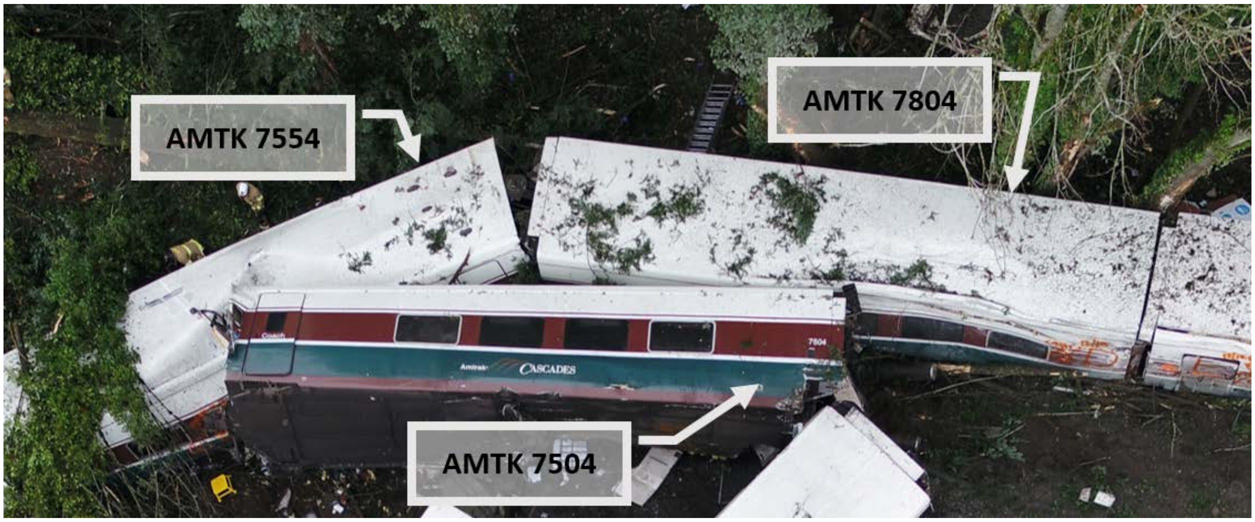


Figure 8. AMTK 7504 resting on AMTK 7554 and AMTK 7804. (Photo WSP)

AMTK 7804 came to rest upright in the woods, oriented primarily in its original direction of travel, with the coupled connection deformed but intact between it and AMTK 7554. AMTK 7804 sustained a longitudinal gouge about 13” high on the right side consistent with a raking collision from the car abrading the concrete wall immediate to the right side of the track at MP 19.86. AMTK 7504 was positioned on its side straddling AMTK 7554 and 7804. The gouge mark along the upper left roof of AMTK 7804 aligns with final position of AMTK 7504 consistent with AMTK 7504 traveling along the top left side of AMTK 7804 to its final resting position.

AMTK 7303 came to rest upright in the woods, mechanically coupled and aligned with AMTK 7804. AMTK 7303 followed a similar trajectory as AMTK 7804. AMTK 7303 exhibited similar scrapes and a continuous longitudinal gouge mark along its right side, consistent with a raking collision during its post-derailment movements.

AMTK 7504 came to rest on its left side against the left upper side/roof of AMTK 7554 and against the left side of 7804. The resting position of 7504 indicates that during the collision it rotated 180°, aligning its trailing end to the southeast. The rotation of AMTK 7504 was consistent with the run-in forces from the cars and locomotive behind it providing it with rotational energy as the derailing cars slowed to a stop.

The side wall of AMTK 7504 was structurally compromised on its left side suggesting it collided with a rigid structure during its rotation. Human remains consistent with a deceased passenger riding in AMTK 7504 were located immediately prior to the bridge near a concrete foundation suggesting the left side wall was compromised prior to coming to its final resting location. The car's final position was adjacent to the right side of the elevated bridge platform.

At its point of rest, AMTK 7504's left side wall was buckled and bowed inward. The entire car bowed inward, and the underframe plastically deformed in a manner consistent with a twisting motion. Laying partially within the left side compromised wall structure of AMTK 7504 was a complete rolling assembly severely deformed (twisted) as shown in figure 9.

Figure 9. Detached rolling assembly against AMTK 7504 (looking north). (Photo WSP)

The towers of the severely twisted and deformed rolling assembly are typically parallel. The wheels of the rolling assembly lay immediately outside of the deformed left side of AMTK 7504. One of the towers of the rolling assembly was partially resting within the passenger compartment against occupied areas within the car. Post-accident observations showed that two of the three deceased passengers in this car came in contact with the rolling assembly at its point of rest. Investigators determined the rolling assembly was from car AMTK 7422. (See figure 10.)

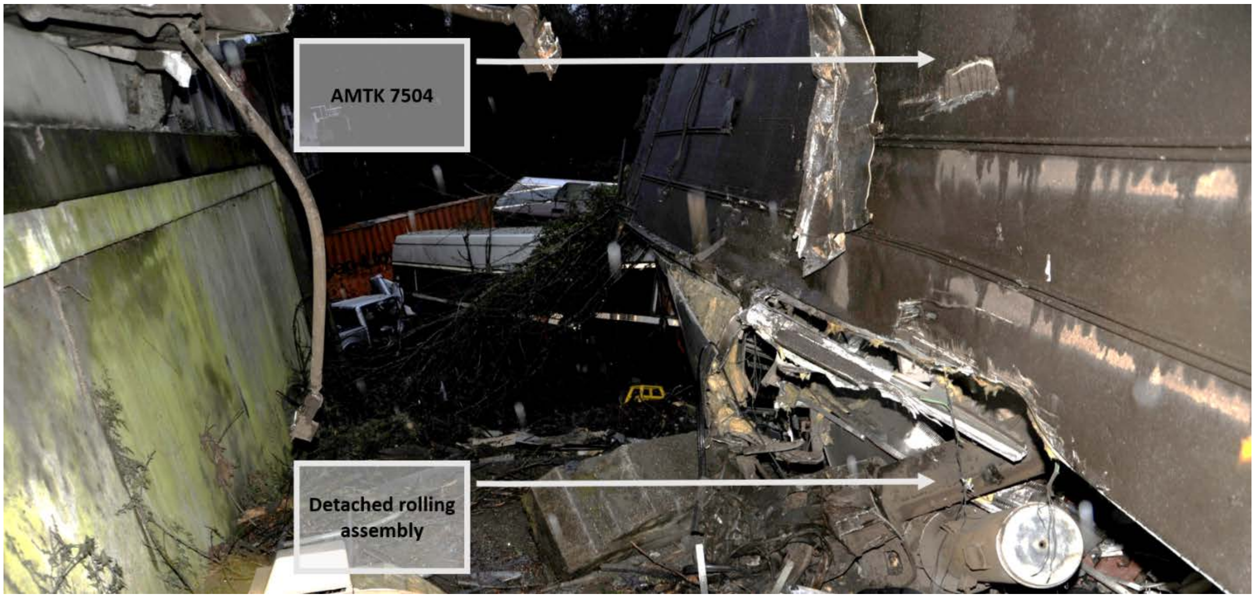


Figure 10. Detached rolling assembly against AMTK 7504 (looking west.) (Photo FBI)

Also located near the compromised left side wall of AMTK 7504, was a concrete structure from the bridge abutment.

AMTK 7424 came to rest on the southbound lanes of Interstate 5 beneath the bridge, on its roof and rotated opposite its original direction of travel. AMTK 7424 was originally coupled to the rear end of AMTK 7504. During the derailment, AMTK 7424 separated from AMTK 7404 and derailed to the left of the main track. This oriented AMTK 7424 toward the left side of the bridge, where a steep embankment descends to the Interstate. (See figure 11.)

Figure 11. Derailment path of AMTK 7424. (Photos WSP)

Inspection of the derailment scene showed no obvious damage to the galvanized steel conduit located on the left side of the bridge abutment nor the street light located on the highway about 30-feet from the bridge wall. Observed damage to the embankment was minimal, witness marks and evidentiary artifacts from the bridge structure (metal railing at the bridge abutment) indicate that the right rear side-wall of AMTK 7424 struck the abutment, tearing the rear portion of the side wall open and the car then traveled off the embankment and rotated end over end onto the Interstate. Post-derailment examination of photos show evidence consistent with the movement of AMTK 7424 sliding along the interstate that align with its final resting position. As AMTK 7424 traveled down the embankment, its rolling assembly detached and, according to witnesses, traveled onto the southbound lanes of Interstate 5 colliding with a green Kia and a black Jeep. Further details can be found in section 1.6.2, Highway Vehicles.

Investigators observed roof damage on AMTK 7424 to be more pronounced toward the trailing end of the car, correlating with a larger more forceful impact consistent with end-over end rotation and a secondary collision with the semi-truck. Orange paint transfer on the left side of the trailing end of AMTK 7424 shows that the orange trailer of the semi-truck trailer impacted it and pushed it further under the bridge.

AMTK 7423 came to rest upright on the bridge positioned across the track, orientated about 50° counterclockwise to the track. The articulated connection between AMTK 7423 and AMTK 7422 failed. The rolling assembly from AMTK 7423 remained near the car but was partially detached. The wheels of the rolling assembly compromised the sidewall of AMTK 7421.

Figure 12. AMTK 7423 partially detached rolling assembly. (Photo WSP)

AMTK 7422 came to rest upright just prior to the bridge rotated about 100° clockwise from its original direction of travel. It was positioned with the rear end on the track abutted against the left side of AMTK 7423 and the front end extending partially over the left side of the embankment just prior to the bridge.

AMTK 7421 came to rest hanging off the bridge held in place by its coupled connection to AMTK 7420 and its front end leaning against the underbelly of the overturned AMTK 7424. As AMTK 7422 rotated clockwise separating from AMTK 7421, AMTK 7421 was directed to the left side of the bridge, through the bridge abutment handrails.

AMTK 7420 came to rest coupled to AMTK 7421 completely derailed with the front end of the car on the edge of the bridge. The coupled connections remaining attached indicates AMTK 7420 followed a similar trajectory from the derailment point as AMTK 7421.

AMTK 7102 came to rest positioned about 15° counterclockwise to the track with the rear rolling assembly, located on the track. AMTK 7102 remained coupled to AMTK 7420.

AMTK 181 came to rest upright, on the track and coupled to AMTK 7102.

1.5 The Accident Train

On December 18, 2017, at 6:10 a.m. Amtrak passenger train 501 departed from Seattle King Street Station heading south towards Portland. The train was a total of 649-feet long and weighed 920,000 lbs. The P-42 locomotive and bistro car 7303 were owned by Amtrak, the Charger locomotive and the rest of the Mt. Adams trainset were owned by WSDOT and operated by Amtrak under contract agreements. (See table 1.)

Sequence	Car type	Road number	Weight (lbs.)	Length (feet)
1	Locomotive	WDTX 1402	265,000	71.5
2	Power	AMTK 7903	43,220	38.7
3	Passenger, business class	AMTK 7454	30,650	43.1
4	Passenger, business class ADA	AMTK 7554	30,650	43.1
5	Passenger, dining	AMTK 7804	27,780	43.1
6	Passenger, bistro	AMTK 7303	31,090	43.1
7	Passenger, coach class ADA	AMTK 7504	31,090	43.1
8	Passenger, coach class	AMTK 7424	31,090	43.1
9	Passenger, coach class	AMTK 7423	31,090	43.1
10	Passenger, coach class	AMTK 7422	31,090	43.1
11	Passenger, coach class	AMTK 7421	31,090	43.1
12	Passenger, coach class	AMTK 7420	31,090	43.1
13	Baggage	AMTK 7102	39,690	38.7
14	Locomotive	AMTK 181	268,000	69.0
Total			922,620	648.9

Table 1-train 501 characteristics

1.5.1 Lead Locomotive Description

The lead locomotive, WDTX 1402, of the derailing train is a Siemens Charger diesel-electric locomotive. The Charger is designed with a single cab and adjacent machinery room. The locomotive unit measures 71.5 ft. (length), by 10 ft. (width), by 14.7 ft. (height), and weighs about 265,000 lbs.

The Charger is powered by a 16-cylinder Cummins QSK95 diesel engine providing up to 4,400 hp. The engine feeds an alternator and the traction converters provide single axle control for 125 mph operation while meeting EPA Tier 4 emissions standards. Head End Power (HEP) 480 Volts (AC) three-phase system is provided at both ends of the locomotive.

The Charger features two (2) two-axle trucks. Each truck is powered by two transversely-mounted AC traction motors, each of which drives an axle by means of a dedicated gearbox. The four traction motors are designated as M1 or M2 for the leading and trailing axles of the front truck respectively, and M4 and M3 for the leading and trailing axles of the rear truck respectively.

The operating cab features a locomotive engineer’s (engineer’s) console that contains all the controls and indicators necessary for the operation a of the locomotive, including three full-screen monitors, designated as Train Operator Display (TOD) 1, 2, and 3. Two of the displays are located at the engineer's side and one at the assistant engineer's/conductor’s side. Also located in the operating cab are the windshield and wiper assembly, and the seats for the engineer and assistant engineer.

Lighting for the Charger consists of an exterior and interior system. The exterior lights include headlights, marker lights, auxiliary lights, and step lights. The interior lights are made up of cab lights, machinery room lights, and console lights.

Monitoring of the locomotive is done with cameras: a forward-facing camera and an inward facing cab camera. Data collected by the cameras via the Locomotive Digital Video Recorder (LDVR) is recorded and stored. The LDVR also includes front-mounted and cab microphones that pick up sounds in the direction of travel from the exterior of the locomotive and from the inside of the cab.

The Locomotive Cab Radio (LCR) is mounted on the engineer’s console and allows the engineer several methods of communication, ‘push to talk’ or via handset. Cab speakers are located on the rear cab wall.

1.5.1.1 Siemens Inc. in the US

Siemens Rolling Stock business unit is part of the Siemens Mobility Division. Siemens designs and manufactures across the entire spectrum of rolling stock including commuter and regional passenger trains, light rail and streetcars, metros, locomotives, passenger coaches and high-speed trainsets. In the U.S., Siemens is providing rail vehicles, locomotives, components and systems to more than 25 agencies in cities such as Washington D.C., New York, Boston, Philadelphia, Denver, Salt Lake City, Minneapolis, Houston, Portland, Sacramento, San Diego, St. Louis, Atlanta and Charlotte. Siemens has transportation manufacturing hubs in: Sacramento, CA; Louisville, KY; Marion, KY; and Pittsburgh, PA. A list of Charger (SC-44) locomotives in the US constructed under the contract for WSDOT, Illinois Department of Transportation (IDOT) and California Department of Transportation (Caltrans) is shown below.

Agency	Type	Quantity	Production
IDOT	SC-44	33	2016-2017
Caltrans	SC-44	6	2016-2017
WSDOT	SC-44	8	2017
Caltrans II	SC-44	16 (in delivery)	2018

Table 2. List of Siemens Charger locomotives in the US.

1.5.1.2 Locomotive Crashworthiness Requirements

Locomotive crashworthiness requirements in the United States are governed by FRA regulations and the Association of American Railroads (AAR) standards. The FRA regulations are outlined in Title 49 of the *Code of Federal Regulations* (CFR), Part 229, Subpart D, Railroad Locomotive Safety Standards and, CFR Part 238, Subpart C, Passenger Equipment Safety Standards. The AAR following standards are incorporated by reference: AAR S-580, AAR Manual of Standards and Recommended Practices, Section M, Locomotives and Locomotive Interchange Equipment, Standard S-580, Locomotive Crashworthiness Requirements and AAR S-5506, AAR Manual of Standards and Recommended Practices, Section M, Locomotives and Locomotive Interchange Equipment, Standard S-5506, Performance Requirements for Diesel Electric Locomotive Fuel Tanks. The Siemens locomotive was designed to meet all US requirements.

1.5.1.3 Siemens Crashworthiness Design

The Charger locomotive is an integral monocoque wide-body, single cab design, suited for push-pull operation. The carbody is comprised of five major elements: underframe, side walls, cab, rear wall, and four detachable roof sections (roof panel numbers 1, 2, 3, and 4). It is designed to allow compression forces of 800,000 lb. (400 ton) of buff load and is equipped with an AAR Ftype coupler with a push-back mechanism to achieve full anti-climber engagement. A select list of its design features is outlined below:

- Longitudinal load of 800,000 lbf
- End frame loads of 200,000 lbf on either side of coupler
- Horizontal collision post loads of 500,000 lbf even with the top of the underframe, 200,000 lbf at 30 inches above the underframe, and 60,000 lbf anywhere along the underframe applied in +/-8° to the longitudinal axis
- Corner posts loads of 300,000 lbf longitudinal at the top of the underframe, 100,000 lbf longitudinal and lateral at 18 inches above the underframe, and 45,000 lbf anywhere along the underframe
- Upward and downward load of 100,000 lbf at the anti-climber
- 2g vertical load applied on the mass of the truck
- Shear load of 250,000 lbf in any horizontal direction on the truck along with the resulting vertical reaction to this load
- Downward load of 100,000 lbf at the coupler carrier.

A crash energy management (CEM) system is incorporated into the mechanical couplers. A multi-stage deformation tube is designed into the draft gear system and will absorb up to 1,200,000 lbf at each end of the locomotive. Activation of the deformation tubes is indicated by plates hanging down from the headstock and visible from outside the locomotive. The coupling system can transfer a 250,000 lb. draft load at any time during the push back sequence. The uncoupling mechanism is designed to handle the complete push-back motion of the coupler without activation of the coupler lock mechanism. Further, a plate impedes the lock to lift-up when the coupler is pushed back.

The locomotive engineer is protected by a safety cage comprised of different structural members such as side sill, head stock, collision posts, corner posts, structural shelf, roof rail, top cross member, door posts and front sheathing. In case of an accident with another rail road vehicle the coupler pushes back and the anti-climber interlocks. The arrangement of anti-climber and coupler complies with AAR S-580 section 6.1.

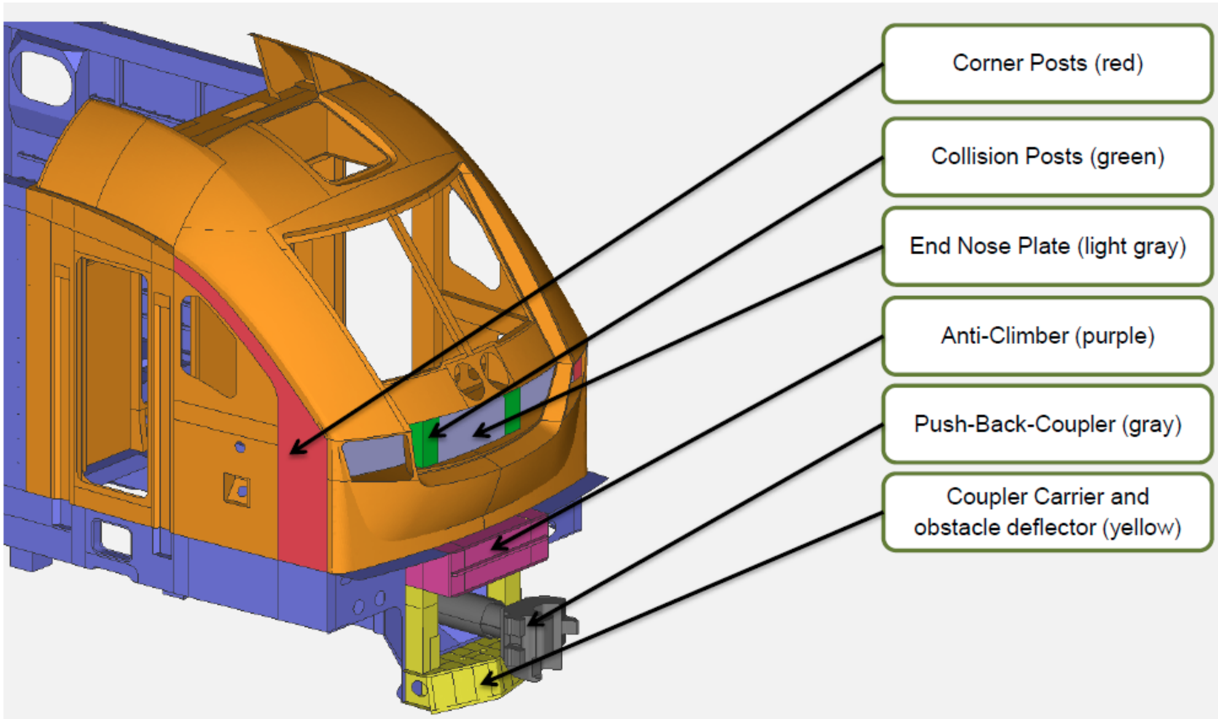


Figure 13. Siemens Charger locomotive crashworthiness features.

1.5.1.4 Post-Accident Observations and Inspections

During the on-scene phase of the investigation, investigators observed localized post collision deformations to the front of the operating cab above the corner and collision posts. The operating cab windshield was destroyed; however, the laminated safety glass feature prevented the shattered glass from separation into pieces. The right side of the locomotive exhibited non-structurally compromising sidewall damage consistent with the locomotive being on its side. Abrasions were visible along the entire length, from the side sill (lower portion along the floor line) to the roof. The rear end wall structure was severely loaded during the derailment and was separated from the right side wall connections. The left side connections remained intact. Damage along the left side was minimal. The roof panels (three total) were severed from their connections.

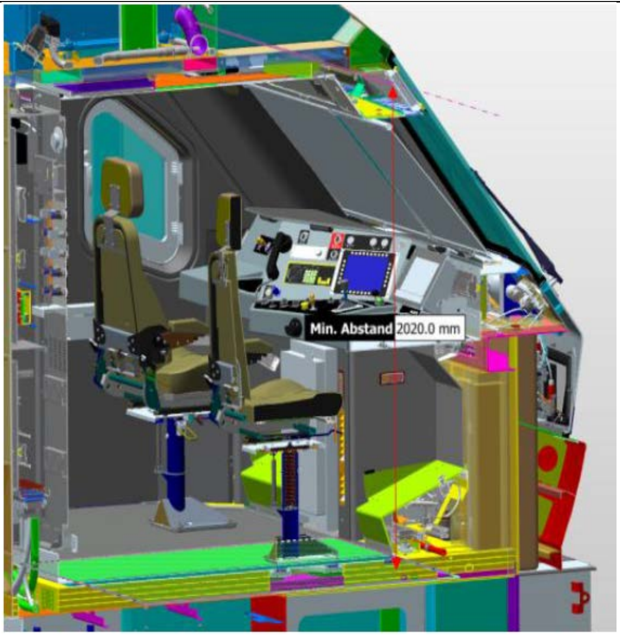
Figure 14. Front of WDTX 1402.

Figure 15. Right side of WDTX 1402.

At the instruction of NTSB investigators, additional post-accident observations and examinations were completed by Siemen's engineers in January of 2018, at Joint Base Lewis–McChord (JBLM), a storage site where the damaged equipment was moved to. They reported there were no visual separations of the corner and collision posts, or visual separations or ruptures of the welded seams. Both side entry doors of the engineer's cab and the machine room access door were operable. The underframe was locally deformed, but the structural condition was intact. The CEM in the front and rear coupler was not activated. Both trucks and their retention mechanisms remained intact and attached to the locomotive. The fuel tank and the fuel tank inlet were not compromised because of this derailment. The roof panels were not evaluated.

1.5.1.5 Locomotive Survival Factors

The damage to interior of the operating cab was constrained primarily to the leading end, most notably at and above the front glazing (windshield). The vertical space of the cab interior was reduced to approximately 19-inches between the operator's desk and the ceiling, and to 66-inches from the floor to the ceiling. The height above the seats was reduced by 13-inches from originally 79.5-inches. All doors, both side doors and the machinery room access door, were fully functional after the crash. The cab ceiling emergency exit hatch was dislodged from the vehicle. The hatch is comprised of two parts. The upper, or outer, part came to rest in the wooded area between the track and the interstate and the inner portion was inside the cab. Investigators estimated the locomotive lost about 5% of its occupied volume in the cab.

 Figure 16. Illustration of the cab design.	 Figure 17. Photograph of the damaged locomotive cab.

The locomotive engineer sustained blunt impact trauma to the head, facial fractures from impact with the interior structures that collapsed due to the impact with the trees and a fractured right elbow from impact with the console. The qualifying conductor who was also in the operating cab, sustained injury to his lower extremities, back and spinal injuries and blunt impact trauma to his torso.

1.5.2 Passenger Car Descriptions

The passenger cars involved in this derailment were designed and manufactured by Talgo, Inc (Talgo). The Talgo passenger train is a 12-car articulated passive tilting trainset comprising of 10 passenger cars of various type situated between unoccupied end cars. One end car contains two small diesel alternator sets with an associated fuel tank for auxiliary power and the other end is a baggage car. The Talgo trains have operated with a converted locomotive ("cab-baggage car") used as a cab control car at the end of the train opposite the locomotive. (More on the operational details are discussed below.)

The accident trainset is known as the “Mt. Adams” Talgo Series VI trainset manufactured by Talgo, Inc. It is a unique design in the US passenger rail industry. Each car of the trainset is semi-permanently coupled to the adjacent car through an articulated connection. This connection cannot be uncoupled like traditional mechanical couplers. The trainset is retained in its configuration unless special tools are used by mechanical personnel in a qualified maintenance facility to separate the cars.

The Talgo Series VI passenger cars are approximately 43-feet in length and 9 ½ -feet wide. The car shell is comprised of silicon magnesium aluminum alloy extrusions welded to each other, forming a self-supporting unit. Two automatic exterior doors are located on either side of only business class cars and coaches, at the suspended end of the car. This trainset is designed with one rolling assembly located between each passenger car, except for the baggage car which has two rolling assemblies. See figure 18.

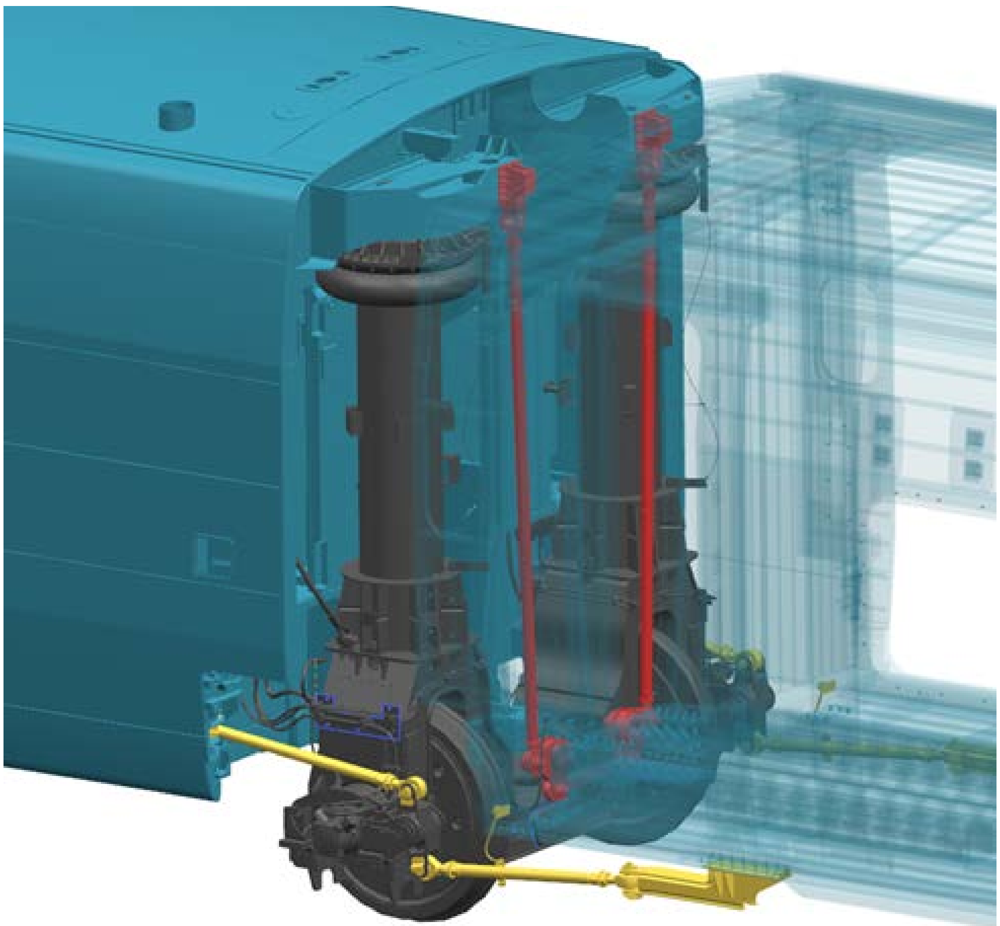


Figure 18. Illustration of a rolling assembly configured between cars.

The wheels are not connected with a traditional axle, but rather mounted on 'stub axles' allowing each wheel to independently rotate. The wheels and stub-axles are mounted in a frame assembly which is in turn mounted to two vertical columns known as towers. The towers are attached to pneumatic diaphragms which serve as an active suspension system. The diaphragms are mounted to the top of the car body in a framed assembly mounted to the end wall of the supported end of the car.

Two weight bearing bars (shown in red in figure 18) are attached to the supported ends of a car (at the top near the air springs) and are joined to the opposite end of the adjacent car. This end of the adjacent car is referred to as the ‘suspended end’. The weight bearer system supports the vertical load between each car. Each car in the trainset has one supported end and one suspended end, except for the baggage car, which does not have a suspended end.

Each rolling assembly is attached to the two adjacent units through upper and lower guidance arms (shown in yellow in figure 18). The guidance arms serve as the primary attachment of the rolling assembly to the car bodies; however, their primary purpose is to position the stub axles perpendicular to the rail on tangent track and radially in a curve. They are needed because the lack of an axle connecting the left and right wheels at each location means the wheel taper will have no ability to steer the wheels. These arms achieve their purpose by acting through a 1:1 bell crank attached to the outboard bearing boxes, splitting the difference in distance between car bodies on each side, right and left, thereby keeping each wheel and axle half-way between the two in all conditions. (See figure 19.)

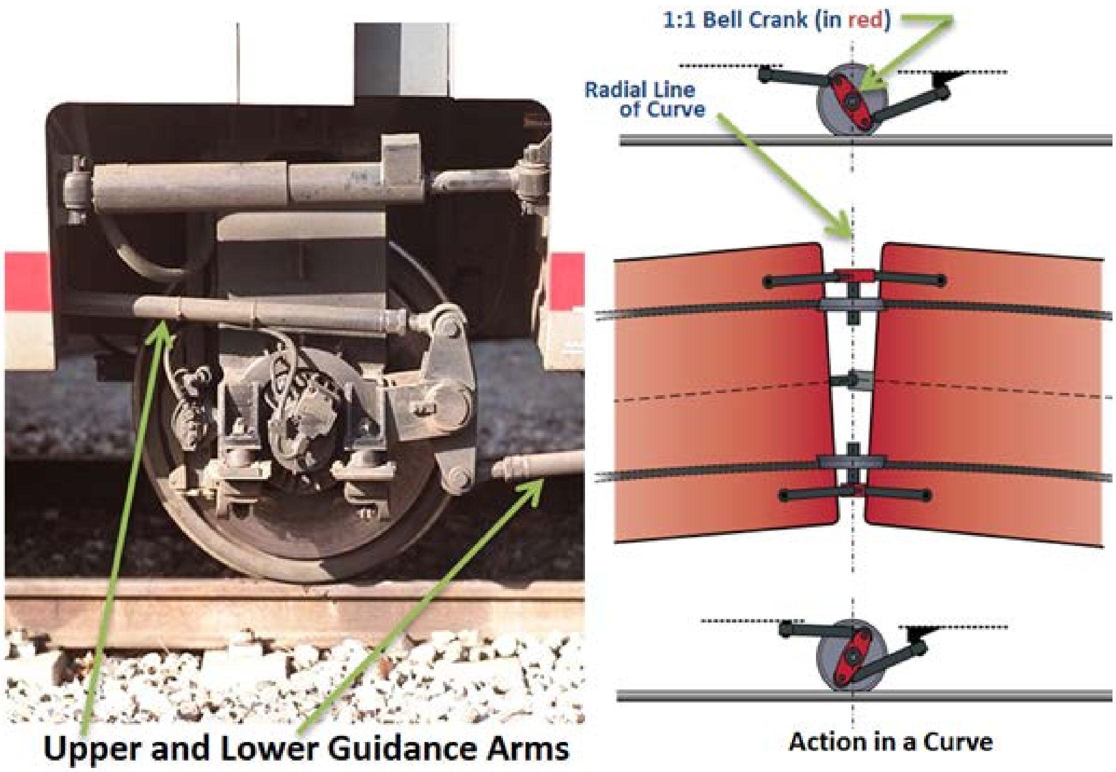


Figure 19. Illustration of the rolling assembly guidance arms.

Along with the minor addition of a lateral snubber (shock absorber), these arms form the only positive attachment between the rolling assembly and the adjacent car bodies on all Talgo equipment worldwide.

However, to meet FRA grandfathering requirements to operate in the US, a supplemental attachment was needed, thus the five train sets in operation in the US, including the Mt. Adams trainset, have a system of support cables and safety straps serving as additional components to retain the rolling assemblies to the car body.[5] There are two vertical cables, approximately ½-inch in diameter connecting the rolling assembly frame to the upper portion of the supported end of the car. Each of the two tower supports has a 2-inch wide four-layer strap wrapped around the tower and connected to a hook mounted on the end wall of the supported end carbody. There are also four straps connecting the end walls of the supported and suspended end of the cars to the rolling assembly frame itself. In summary, there are 6 straps and 2 cables that serve as the rolling assembly retention system between each car. (See figure 20.)[6]

[5] The grandfathering requirements are discussed in section 1.5.2.4, Grandfathering Talgo Passenger Cars.
[6] More information is available on the safety straps in section 1.10, Tests and Research.

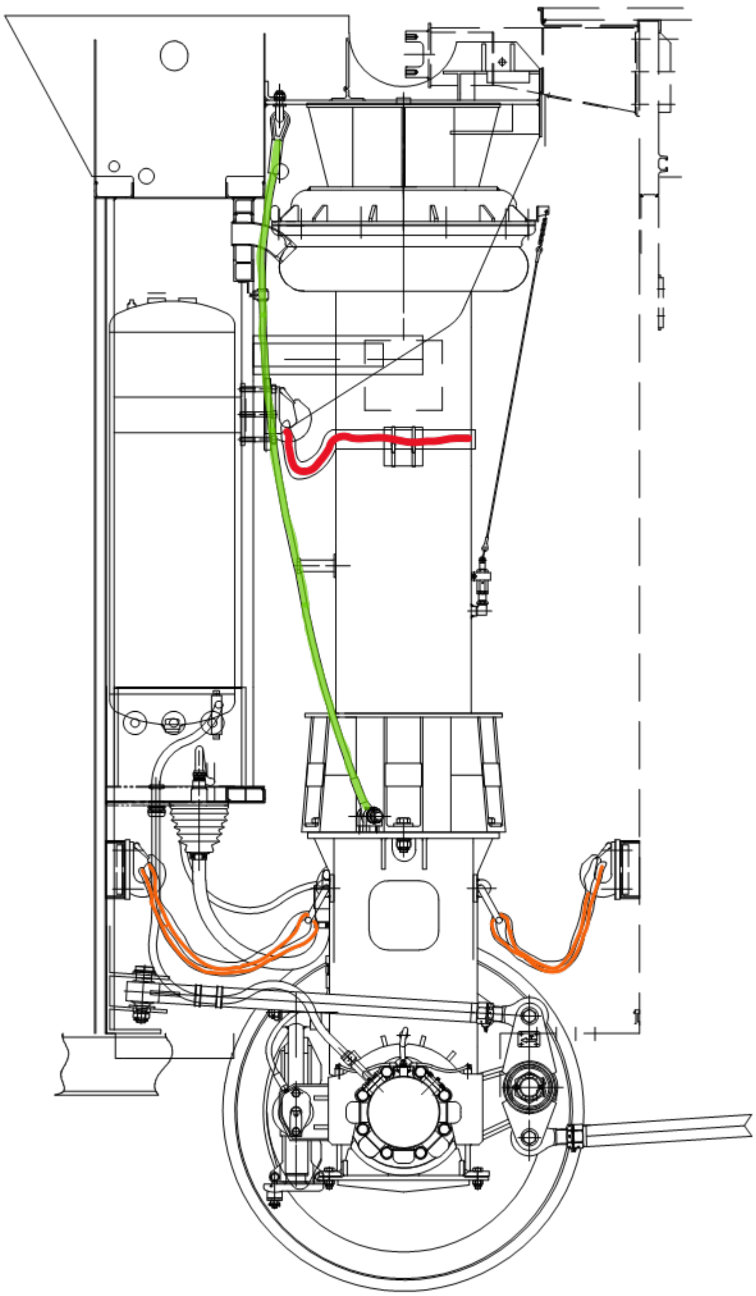


Figure 20. Illustration of a rolling assembly and attachment system.

1.5.2.1 Talgo in the United States

Talgo's current presence in the United States began in 1988 when Amtrak conducted test runs with Talgo tilting cars to establish the performance of high cant deficiency operation in the

North East Corridor.[7] Talgo's presence in the United States broadened in 1994. In April, Renfe-Talgo of America (a joint venture between Renfe, the Spanish National Railways and Talgo) was awarded a contract by the WSDOT to lease a Talgo trainset for operation in the Seattle, Washington to Portland, Oregon corridor for six months.

In October of 1994, showcase runs of the Talgo rolling stock were performed for railway authorities and technical experts in Oregon, California, Missouri, Ohio, Pennsylvania, Massachusetts, New Hampshire and Maine. The contract with WSDOT was also renewed for an additional six months.

Ridership continued to grow and, in July of 1996, WSDOT and Amtrak placed an order to buy three new Talgo TPU™ trains (two by WSDOT and one by Amtrak). Amtrak further agreed to lease one additional train, which was ultimately purchased by Amtrak. These trains were assembled in Seattle using American labor and parts. The new Talgo trains started service in February 1998 and are operated by Amtrak under the Cascades® brand name.

A fifth trainset was manufactured at the same time as the four previously mentioned. This trainset was scheduled to enter service between Los Angeles, CA, and Las Vegas, NV, in early 2001, but was sold to WSDOT in 2003. At the time of this report, the trainset is not in use because it was destroyed in this accident.

Talgo made an agreement in 2009 to build a manufacturing facility in Wisconsin which would initially supply two 14-car trainsets for the Amtrak Hiawatha Service. The Series 8 Talgo passenger cars are similar to the Series VII cars (used in Europe), but are designed for the North American market. Shortly before the Wisconsin equipment was completed, the citizens of Wisconsin elected Scott Walker as their governor. He had run on a platform with a “stop the train” campaign and did just that. The $810 million Madison-to-Milwaukee passenger rail project was halted in November 2010. The Wisconsin trainsets were not placed into service and thus sent into storage at Amtrak’s Beech Grove (Indianapolis) facility.

[7] The term *cant deficiency* is defined in the context of travel of a rail vehicle at constant speed on a constant radius curve. Trains operating in curves experience a lateral force to the outside of a curve that is a function of velocity. When the outside rail is elevated (*super elevation*) the lateral force is reduced or balanced. The degree to which the force is not fully balanced is referred to as ‘cant deficiency’. It is quantified as the additional super-elevation needed to fully balance the lateral force.

In February 2010 Oregon ordered two (2) additional trainsets to secure and expand passenger rail service in Oregon as well as to support the growing rail ridership in the Pacific Northwest. The trainsets were delivered at the end of 2013 and were put in operation on January 7, 2014. The trains were designed to meet all FRA regulations and were mostly manufactured in the US.

In the wake of the December 18, 2017, train 501 derailment, Amtrak proposed to lease or buy two Talgo trainsets which were originally bought for use in Wisconsin but never operated. If the lease/purchase is acted upon, these two additional Series 8 trainsets will be integrated into the Cascades service.[8]

The total number of Talgo trainsets in the US is shown in the table below.[9]

Organization	Car Series	Trainsets	Cars	Production
Amtrak	Series VI	2	29	1998
WSDOT	Series VI	3	38	1998
Oregon DOT	Series 8	2	26	2013
Wisconsin	Series 8	2	31	2013

Table 3-Talgo trainsets in the US.

1.5.2.2 US Crashworthiness Standards

At the time the Talgo cars were delivered to WSDOT, passenger car crashworthiness requirements were limited to a static end strength of 800 kip (kilo-pounds). The requirements were prescribed in AAR Standard S–034–69, Specification for the Construction of New Passenger Equipment Cars, published in 1969. Section 6, paragraph (a), of the specification required that the car structure shall resist a minimum static end load of 800,000 lbs. at the rear draft stops ahead of the bolster on the center line of draft, without developing any permanent deformation in any member of the car structure. The static end strength requirement was based on longstanding practice and originated in specifications for U.S. Railway Post Office (RPO) cars in the 1940's.[10]

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[8] Talgo abandoned the use of Roman numerals after the series VII trainset.

[9] This table reflects the quantity prior to the derailment on December 18, 2017.

[10] Tyrell, D., "U.S. Rail Equipment Crashworthiness Standards," presented at "What can We Realistically Expect from Crashworthiness?" Rail Equipment Crashworthiness Symposium, Institute of Mechanical Engineers, May 2, 2001,London, England. Talgo contends the RPO dates back to 1912 rather than the 1940s, Railway Mechanical Engineering, a Century of Progress, Car and Locomotive Design ASME Rail Transportation Division, American Society of Mechanical Engineers, 1975. David G. Blaine, editor. Library of Congress 79-64377.

Numbers of earlier RPO cars, which were built to lower static end strength requirements, were crushed in train collisions. During a collision, substantial compressive loads would be applied to such cars. For cars not built to the 800 kip static end strength requirement, the results could be catastrophic, with structural collapse of the cars and many postal workers killed. The introduction of cars that met the 800 kip static end strength requirement effectively eliminated this type of complete structural collapse.

On May 12, 1999, the FRA published a Final Rule regarding Passenger Equipment Safety Standards. This Rule became Title 49, *Code of Federal Regulations* (CFR) Part 238 [See: 64 FR 25540]. In the section for Structural Standards for Existing Equipment, the final rule requires that all passenger equipment (other than locomotives that comply with an alternative standard as specified, private cars, unoccupied vehicles operating at the rear of a passenger train, or equipment used in non-commingled service, as discussed below) in use on or after November 8, 1999 have a minimum static end strength of 800,000 pounds as specified in 49 CFR § 238.203.

In addition to the static end strength requirement, requirements in the 1999 final rule for passenger car strength included: (summarized)

- Anti-climbing mechanism at the forward and rear ends capable of resisting an upward or downward vertical force of 100,000 lbs. without failure
- Link between coupling mechanism and carbody such that equipment shall have a coupler carrier at each end designed to resist a downward thrust from the coupler shank of 100,000 lbs. for any normal horizontal position of the coupler without permanent deformation
- Two full height collision posts having an ultimate shear strength not less than 300,000 lbs. at a point even with the top of the underframe member to which its attached to
- Two full height corner posts capable of resisting a horizontal load of 150,000 lbs. at the point of attachment to the underframe without failure
- Truck-to-carbody attachments shall have a truck-to-car-body attachment with an ultimate strength sufficient to resist without failure the following individually applied loads: 2g vertically on the mass of the truck; and 250,000 lbs. in any horizontal direction on the truck, along with the resulting vertical reaction to this

load. For purposes of this section, the mass of the truck includes axles, wheels, bearings, the truck-mounted brake system, suspension system components, and any other component attached to the truck by design.

1.5.2.3 Talgo Crashworthiness Design

The Talgo passenger trainset was originally designed to meet the International Union of Railways (UIC) design codes (also known as leaflets). The codes include several design standards much like the AAR design standards here in the US. Specific to the construction of the carbody, the Talgo passenger cars were designed to meet the UIC-566, Loadings of Coach Bodies and their components, revision January 1990.

According to UIC-566, the body of the passenger car comprises the underframe, the side walls, the end walls and the roof which form a tubular beam. The principle design characteristics of the car which are, according to the leaflet, obligatory provisions, are as follows:

- The end walls, strengthened by anti-collision pillars, shall be so joined to the headstocks, cant-rail and roof that the maximum amount of energy is absorbed first by deformation of the end wall section before the passenger compartments are deformed
- The coach body, in running order and mounted on the bogies, shall be designed that under all conditions its natural frequencies differ from the hunting and pitching frequencies of the bogie [truck or rolling assembly], so that no resonance occurs throughout its speed range.

The car body shall be designed to withstand a 2000kN [449,617 lbs.] static compressive loads at the buffer or coupler level without permanent deformation. UIC-566 does not prescribe a structural strength requirement for anti-collision pillars at the car ends.

Additional requirements in UIC-566 include the strength of the component parts mounted on coaches as such, the loads developed resulting from buffing impact (collisions) the following accelerations, acting on the dead weight of the components shall be assumed in the design of the fastenings:

- Longitudinally: 5g
- Transversely: 1g

- Vertically: (c)g (including gravity), where c = 3 at the end of the coach, falling linearly to 1.5 at the coach center.

For the end car, the power car and the baggage car, Talgo designed these to be more restrictive than the requirements in UIC-566.

Load case	Talgo requirement	UIC-566
Longitudinal	6g	5g
Lateral	3g	1g
Vertical	3g	c
Main attachments loading cases.		

Table 4.UIC-566 vs. Talgo end car design load cases.

According to Talgo, no specific requirements are prescribed in UIC-566 for retention of rolling assemblies.

1.5.2.4 Grandfathering of Talgo Passenger Cars

Because of the enactment of FRA's 1999 final rule, Amtrak, by letter dated October 18, 1999, petitioned the FRA pursuant to Title 49 CFR section 238.203(d) to grandfather or permit the use of Talgo articulated trainset on three corridors; the Pacific Northwest corridor between Eugene, Oregon and Blane, Washington via Portland and Seattle, the Southern California corridor between San Luis Obispo and San Diego via Los Angeles; and the corridor between Los Angeles and Las Vegas Nevada.[11] FRA approval was required because the train sets did not meet the required compressive strength of 800,000 pounds applied on the line of draft without permanent deformation of the body structure.

Title 49 CFR section 238.203(d), Grandfathering of non-compliant equipment for use on a specified rail line or line, provides a provision for a railroad to petition the FRA to permit the use of rail equipment not meeting the then newly published requirement(s). The petitions submitted were required to include (summarized): detailed drawings and material specifications, engineering analysis sufficient to describe the performance of the static end strength and its performance in a

[11] During review of this report, Talgo informed the NTSB that a Series VI car was tested in compression in Pueblo, Colorado. The test loads were not applied at the buff stops because the car arrangement does not have them and, according to Talgo, the buff forces produced in a collision are not reacted entirely at the coupler. According to Talgo, the car supported the required 800,000 pound force test without permanent deformation.

collision, risk mitigation efforts employed in connection with the use of the equipment and a quantitative risk assessment demonstrating the use of the equipment, in the service environment, is in the public interest and is consistent with railroad safety.

The FRA received a substantial number of filings for this petition, and several were quite extensive.[12] A public hearing was held on July 21, 2000, at which testimony was received from nine persons representing Amtrak, WSDOT, Talgo, the National Association of Railroad Passengers, the American Public Transportation Association, and Bombardier. FRA considered the public comments in reaching their preliminary decision in September of 2000 and subsequently authorized the use of Talgo Series VI subject to certain conditions.

A summary of select conditions required appear below.

- The rail cars must be modified to increase the strength of the weight bearing bars (two per car) and their related supports to the car structure, to withstand, at a minimum, a 100,000-pound vertical load, applied either up or down
- The rail cars must be modified by applying safety cables between the cars and bogies to resist a minimum total longitudinal force of 77,162 pounds to resist separation of the car-bodies and rolling assemblies[13]
- The rail cars must be modified by applying safety cables around the top of each suspension column, affixed to the upper structure of the cars to resist the application of a nominal 250,000-pound force, applied at the center of gravity of the rolling assembly
- Amtrak must operate the cars in dedicated trainsets as proposed in their submission. When operating in revenue or deadhead service, the baggage and power cars shall be placed at the ends of the remaining cars in the trainset and must not be occupied by passengers or crew
- The trainsets may be operated in either locomotive-hauled or push-pull service. In locomotive-hauled service, the trainset may be followed by a locomotive-type cab control car (e.g., de-powered F40) at Amtrak's election. In push-pull service,

[12] See FRA public docket at https://www.regulations.gov/docket?D=FRA-1999-6404. Selected attachments will also be referenced in this report, see section 2.0 Attachments.
[13] *Bogie* refers to the wheel-axle-frame assembly under each end of a car or locomotive

revenue and deadhead trains must be operated with a locomotive or locomotive-type cab control car on both ends. In either locomotive-hauled or push-pull service, additional equipment in the train consist (e.g., passenger cars, freight cars, materials handling cars, and bi-modal equipment) is prohibited.

- Maximum operating speed is 79 mph
- Amtrak must prepare an engineering analysis reviewing the design and securement of the steel structure affixed to the power car and the baggage car that contains the draft gear and collision posts

In making its final decision, the FRA established they [FRA] must determine that if in the context of a particular rail operation, the absence of otherwise compressive end strength causes the equipment to fall short of the performance that would be expected of equipment having the otherwise required strength, so that its use was consistent with railroad safety. According to the FRA, the central purpose of buff strength is to ensure adequate compatibility among units of rolling stock used on the general railroad system with respect to collision risk. In making its final decision the FRA reviewed the petition and all available information related to the construction of the Talgo trainsets, including (summarized):

- Results of finite element analysis provided to Amtrak by Talgo
- A one-dimensional lumped mass analysis conducted by LTK Engineering for Amtrak
- Photographs of accidents in Europe involving equipment of similar construction
- Public comments

In addition to the relevant information above, FRA also considered (summarized):

- A risk assessment completed for Amtrak by Arthur D. Little Inc. (ADL) The risk assessment evaluated the impact of using Talgo trainsets in the Pacific northwest.
- A crashworthiness evaluation of the Talgo Series VI completed by Volpe National Transportation Systems Center
- FRA engineering staff inspected Talgo equipment and reviewed operational issues that would have arisen since the introduction of the equipment
- Additional risk assessments by ADL

Overall, the FRA concluded that the engineering and other analysis provided assurances that the Talgo equipment could be expected to operate safely on the basis of moderate energy events (50 mph or less) which would present a higher probability of occurrence than more severe events.

In their docket, FRA expressed concern regarding the expected performance of the Talgo equipment in higher energy events. FRA stated that at closing speeds (referring to collisions), the Talgo train was expected to experience a greater lateral displacement than conventional equipment, and articulated connections were expected to fail. Thus, in collisions greater than 25 mph, the following dangers could arise (summarized):

- With failure of the articulated connectors that suspend the car bodies, in the absence of compressive forces, the light car bodies would be free to fall to the track structure or surrounding terrain with unknown results. (Conventional cars are supported by trucks designed to remain attached except under very unfavorable circumstances.)
- Comparatively greater lateral displacement of the passenger units would create a greater hazard of secondary collisions (e.g., by fouling an adjacent main line or impacting with a bridge structure or abutment).

In summary, the FRA determined there was sufficient information submitted to establish that the five Talgo Series VI trainsets could be operated consistent with railroad safety in the Pacific Northwest Corridor at speeds up to 79 mph; or maximum speeds not exceeding 110 mph subject to specific conditions tied to review and approval of the train control system. The trainsets and their predecessors [according to the FRA] had operated without incident on this corridor since 1994. FRA further concluded that the trainsets can be operated consistent with railroad safety on the Los Angeles-Las Vegas route at speeds up to 79 mph.

Amtrak and the Volpe Center had provided and developed information to characterize the crashworthiness of the trainsets under the conditions specified. However, given the uncertainty related to the crash analysis, risk assessment, and other issues discussed above, FRA determined that the conditions attached to their approval would be necessary to secure a reasonable level of confidence that safety would not be compromised.

Final approval was granted by the FRA on March 27, 2009 for the operation of 67 Talgo Series VI cars (five trainsets) having met the conditions discussed above along with: (summarized)

- Restricted to operations between Eugene, Oregon and the US/Canadian border near Blain, Washington, and the route between Los Angeles, CA and Las Vegas, NV
- Operations on the Pacific Northwest Corridor at maximum speeds not exceeding 110 mph are authorized, consistent with other railroad safety regulations (including, e.g., 49 CFR § 213.345) only upon acceptance by the Associate Administrator for Railroad Safety/Chief Safety Officer of plans for, and installation of, a train control system meeting the requirements of 49 CFR Part 236.

1.5.2.5 Post-Accident Observations and Inspections

Post-accident inspections and observations were completed the week of March 5, 2018, at the JBLM storage site. The investigative team completed examinations and recorded remarkable observations and measurements of the cars involved in this derailment. As mentioned earlier, the accident train was configured to have the supported end of each car facing south or leading in the direction of travel. Front and rear orientations are established as follows: the supported ends [ends with rolling assemblies] will be referred to as the front or the leading end of the car. The suspended end [ends without rolling assemblies] will be referred to as the rear or trailing end. See figure 21.

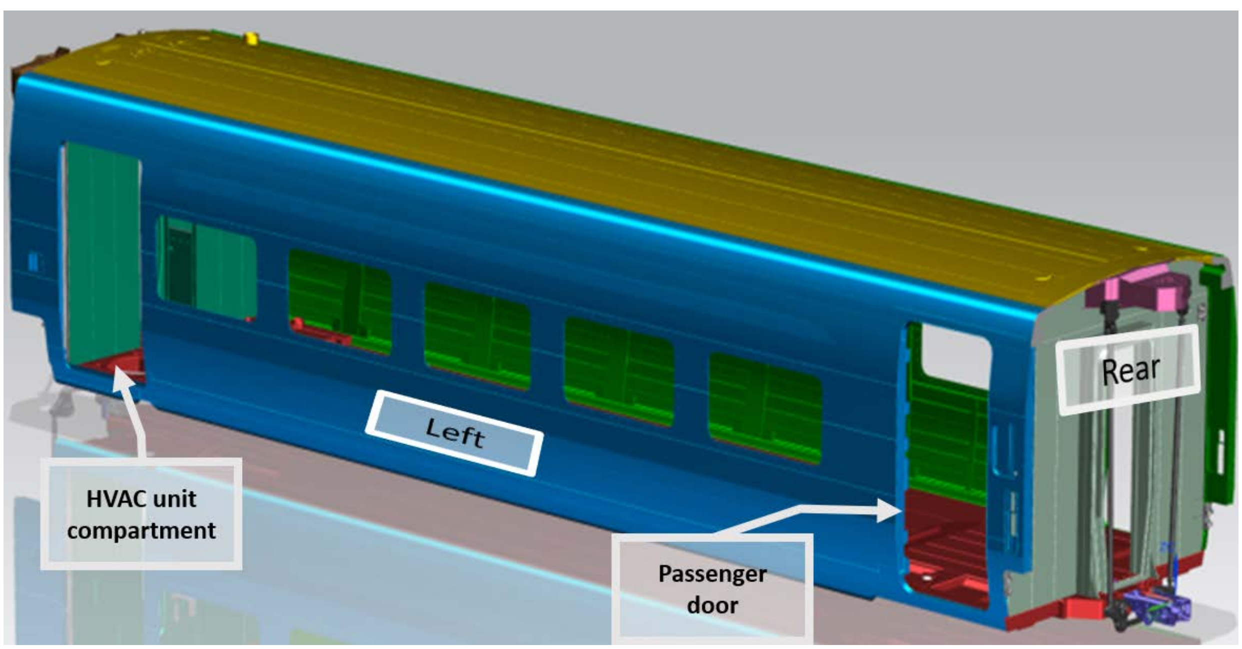

Figure 21. Illustration of Talgo passenger car orientation.

Several references will be made to specific nomenclatures. The illustrations below will serve as the key.

The supported end of the car shown in figure 22 below consists of the rolling assembly (shown in grey), the tower assembly (green) and the air spring suspension (blue).

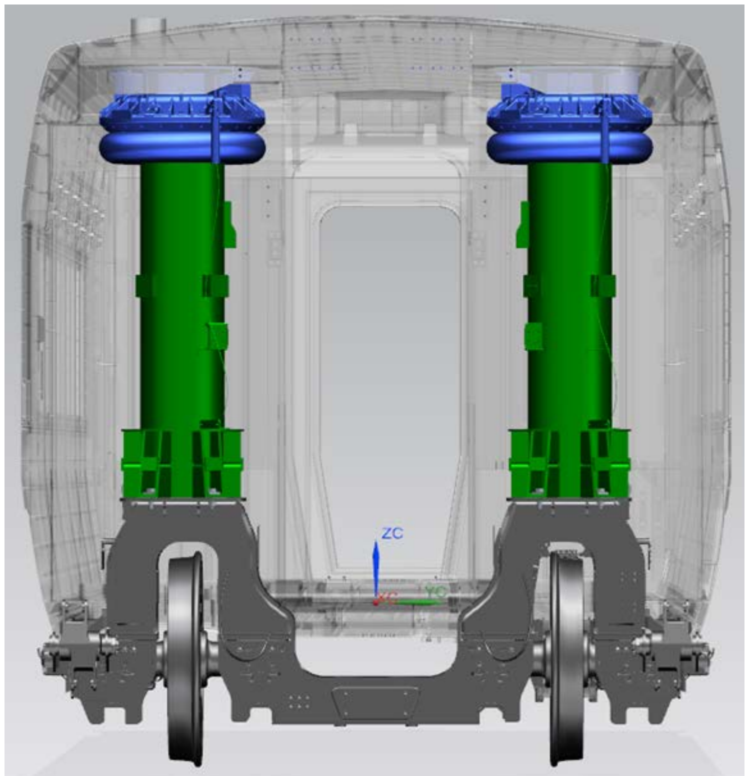

Figure 22.Supported end of Talgo Series VI car.

The supported end rolling assembly and tower assembly retention system consists of an upper and lower steering link shown in yellow in figure 23, primary retention cables (green), tower straps (red) and lower retention straps (orange) also shown in figure 23. In this report we will refer to the complete system as *the rolling assembly*.

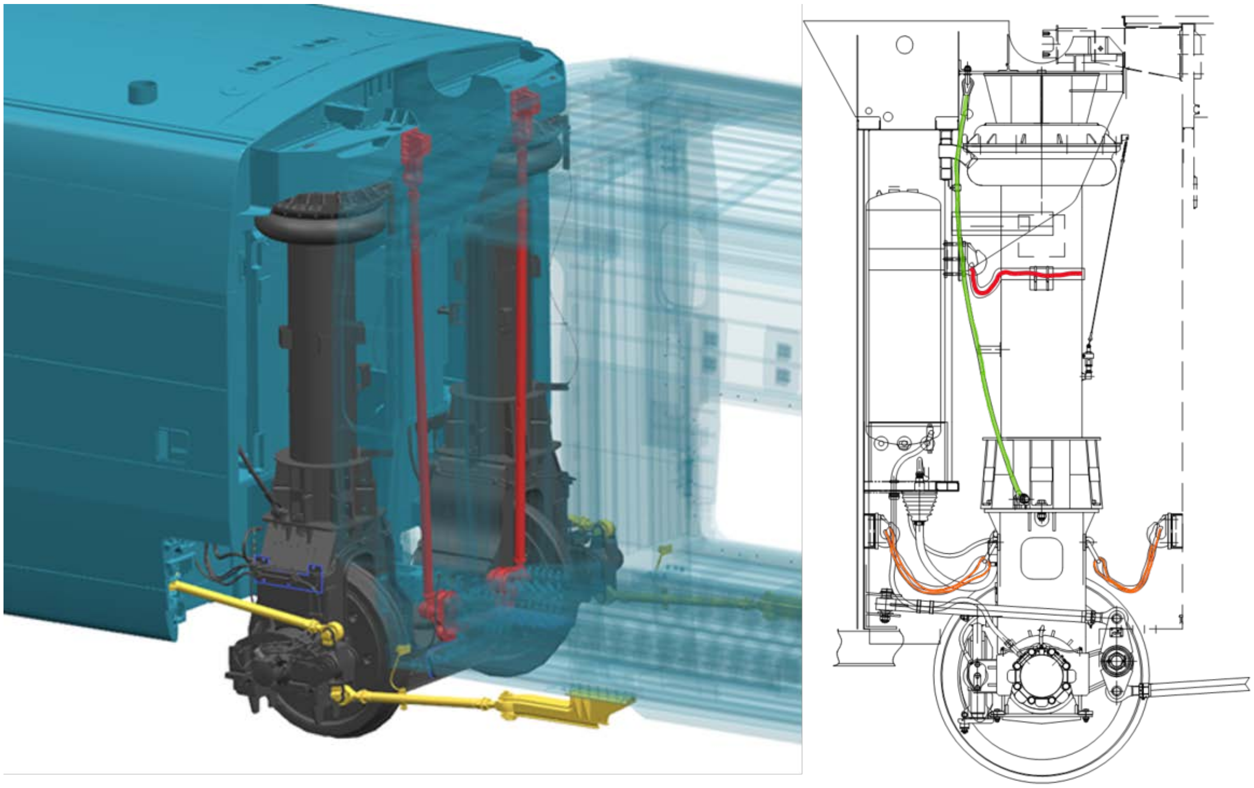

Figure 23. Rolling assembly cutaway and side view.

The suspended end of a car consists of the weight bearer bars (two) shown in red in figure 23. These bars are attached through bolted connections to the supported car. The upper and lower guidance arms are shown in yellow in figure 23. As discussed previously, the guidance arms serve as the primary attachment of the rolling assembly to the car bodies.

The car to car connection or articulated connection consists of two fixtures, each one attached to the car's structure, a shank that joins them together, some stops (buffers) which are mounted on lateral supports to transmit the lateral forces, and a rubber plate which provides it with a certain elasticity when it transmits compressive forces.

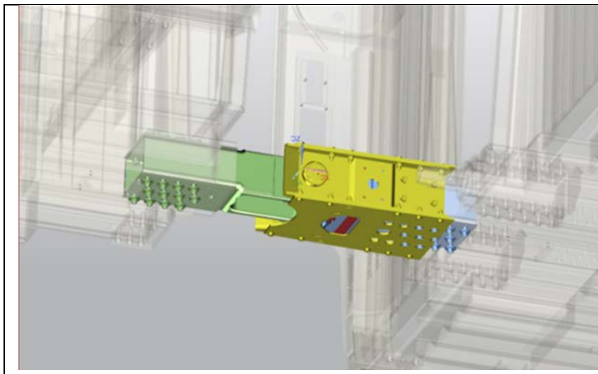

Figure 24. Illustration of articulated connection.

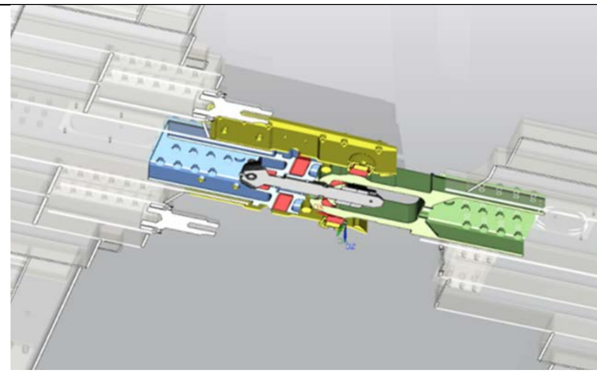

Figure 25. Illustration of interior components of articulated connection.

1.5.2.5.1 AMTK 7903 – Power Car

The exterior side structure of the of the power car [right and left] was relatively intact and was not substantially damaged. The sides were scraped and exhibited impact marks that did not compromise the sidewall structure. The leading end of the power car was damaged as a result from interactions with the locomotive however, the collision posts of this vehicle showed no signs of separation. The leading end right side wall was torn about 4.5-feet toward the rear end of the car. The leading end left side wall was torn about 3-feet toward the rear end of the car. The top upper right and left 'fin' assemblies were not present during this examination although the mounting brackets were. [Post-accident review of at-rest photos reveal the fins were in place, thus their removal occurred during the recovery.]

Figure 26. AMTK 7903 leading end.

The front coupler assembly was fractured, deformed upward and slightly twisted in the counter-clockwise direction when observing from the front. This car has a tank for water and a tank for diesel fuel with filling locations on each side of the car. The fuel fill caps on each side are missing and 265 gallons of diesel fuel spilled on to the ground during the derailment.

The rolling assembly is contained within the carbody on the supported end but otherwise functions the same as other cars in the train. The truck assembly was intact and did not separate from the car, however, the lower steering link on the right side was deformed and the left side was fractured. Investigators observed the lower left retention strap to be intact, but the mounting bracket it was secured to was torn from its welds.

The suspended end load bearer bars were torch cut, but the mounts were undamaged. The hydraulic dampers on the upper and lower left and right side were all destroyed. The guidance bars were severely deformed and overstressed, consistent with separation during the derailment. The hooks designed to hold the lower straps to the underframe were in place, however the truck retention straps were not visible. There were witness marks at the top of the car indicating there were car to car interactions during the derailment.

1.5.2.5.2 AMTK 7454 – Business Class Car

The exterior side structure of the business class car [right and left] was relatively intact and its structure was not substantially damaged. The rolling assembly detached during the derailment and was not observed in place during this examination. Examination of the guidance bars showed indications of overstress and deformation. The articulated connection between AMTK 7454 and AMTK 7903 was severed because of the derailment. When observed, the supported end showed indications of longitudinal loading. The upper left air spring remained in place. The primary steel rolling assembly support cables on the right and left side were broken. The tower straps were broken on the right and left side. The weight bearer supports on the supported end were torn from their mounts. The weight bearer bars on the right and left side of the suspended end were torch cut. The articulated joint on the trailing end remained intact during the derailment and was observed to be torch cut for this examination.

Figure 27. AMTK 7454 Supported end.

Figure 28. AMTK 7454 Right side.

1.5.2.5.3 AMTK 7554 – Business Car ADA Accessible

The supported end of this vehicle retained the wheel assembly and all safety cables and straps throughout the crash sequence. The articulated connection remained intact with AMTK 7454. The exterior right-side structure was relatively intact. There were several indications of a raking collision along the roofline. The left-side structure was crushed inward above the passenger window line at the midpoint of the car. The total loss of occupied volume is estimated at 10%. The supported end rolling assembly was attached during this examination. The primary cable attachment cables were intact, and the tower straps were intact. The weight bearer bars at the supported ends were torch cut, the mounting brackets were intact. The upper right and left steering links were slightly deformed but intact. Investigators noted the right upper steering link jam nut was not engaged. The link exhibited signs of oxidation. See figure 30. The lower steering links were torch cut. The car to car connection (articulated joint) was torch cut.

Figure 29. AMTK 7554 Supported with rolling assembly end and left side.

Figure 30. AMTK 7554 right upper steering link jam nut not engaged and oxidized.

The suspended end had indications of car to car interactions however the end wall structure remained intact. The lower left guidance bar exhibited indications it fractured. The right side appeared to have separated at the threaded portion from overstress. The articulated connection with AMTK 7804 was slightly deformed but remained intact and was observed to have been torch cut during this examination. The left lower safety strap was observed to be broken on the suspended end, the right was missing.

1.5.2.5.4 AMTK 7804 – Dining Car

The exterior right-side structure was structurally intact, and the windows were intact. Two windows on the right side were not in place, apparently from removal during the passenger evacuation. One window exhibited indications of a raking collision and an impact mark that shattered the safety glass in a localized area was present. There was uniform scraping that ran the length of the side wall along the bottom about 16-inches on average from the floor line. The suspended end showed indication of engagement with the trailing car. The articulated connection with AMTK 7303 remained intact during the derailment and the connection was observed to have been torch cut during this examination.

Figure 31. AMTK 7804 Suspended end and right side.

The left side wall structure was scraped and significantly deformed at the suspended end. The roof line structure along the left rear half of the car was structurally compromised and torn. Three (3) passenger windows on the left side were pushed into the passenger compartment and were shattered. The remining two (2) exhibited indication of impacts and were shattered. Uniform witness marks were present along the left side above the window line, consistent with the raking collision from AMTK 7504. The marks were radiused and about 3/8-inches wide extending about 16-feet along the length of the car.

Figure 32. AMTK 7804 left side.

The rolling assembly partially attached detached during the derailment but remained near the supported end of the car when it came to rest. The right side upper guidance bar on the supported end separated during the derailment and the left side was observed to have been torch cut. The supported end weight bearer mounts were observed to be intact. The end structure showed indications of car to car engagement; deformed tower mount structure. The main rolling assembly retention cable and the upper tower straps were observed to be broken. The right side lower horizontal strap hook is broken.

The suspended end wall of AMTK 7804 exhibited indications of car to car interactions as a result of the derailment. The weight bearer bars were observed to have been torch cut as well as the articulated connection. The lower guidance bars were deformed and appeared to have fractured. The lower rolling assembly retention straps were not present. The mounting hook on the left side was observed to have been torch cut, the right was intact.

1.5.2.5.5 AMTK 7303 Bistro Car

The exterior right-side was structurally intact, and the windows were in place. Two windows were shattered, and one was pushed slightly inward in an area that sustained some structural compromise. There was uniform scraping that ran the length of the side wall along the bottom, about 16-inches on average from the floor line.

Figure 33. AMTK 7303 Right side.

The rolling assembly remained in place during the derailment. The rolling assembly was not in place during this examination. The supported end wall structure exhibited damage consistent with car to car interactions because of the derailment. The weight bearer bars were bent, however their mounts on the supported end were intact. The connections [guidance bars] on this end all showed indications of torch cutting as a result of removing the wreckage.

The exterior left side was structurally intact with relatively minor scrapes and abrasions. The side wall at the suspended end was deformed an estimated 18-inches and folded back. One window was shattered, and one was pushed into the passenger compartment. The suspended end showed indications of severe car to car engagement. Fractures were present in the end-wall along the left side floor-line. The left side weight bearer bar was severely deformed and bent, unmounted from its mating car; AMTK 7504. The right-side bearer bar was fractured at the base. The lower guidance bars both exhibited indications of overstress and failed during the derailment. The left and right side lower straps were broken, and the articulated coupler was fractured during the derailment.

Figure 34. AMTK 7303 Suspended end and left side.

1.5.2.5.6 AMTK 7504 Coach Class Car ADA Accessible

The right-side wall structure of AMTK 7504 was intact, with all windows in place. The left side wall structure was severely compromised at the mid-section. The passenger compartment was torn open, buckled inward and the structure was twisted in the area where investigators during the on-scene phase of the investigation observed a rolling assembly laying partially within the left side compromised wall structure. The rolling assembly was severely deformed but remained intact. The wheels of the rolling assembly lay immediately outside of the deformed left side of AMTK 7504. One of the towers of the rolling assembly was partially resting within the passenger compartment against occupied areas within the car. Investigators determined the rolling assembly was from car AMTK 7422.

Figure 35. AMTK 7504 Left side.

The left front quadrant of the supported end separated from the carbody along the side sill and end sill. (Note: the opening is the HVAC unit compartment)The roof on the left side at the mid-section of the car was fully compromised and pushed into the car's passenger compartment approximately 20-inches from the floor. The left side wall separated from the roof and floor at multiple locations. The entire underframe of the car had a twist. The floor of the car had a maximum twist deformation of 29.5-inches high at a point 23.5-feet from the suspended end of the car. The twist began at a point 14.5-feet from the suspended end of the car. The left side of the car had zero remaining occupied volume, resulting in approximately 55% loss of occupied volume. The two wheelchair lifts mounted inside the car near the passenger doors separated from their mounts and were not found within the car.

The supported end of AMTK 7504 exhibited severe structural deformation on the right and left sides. The right-side end wall separated along the floor line and was bowed inward. The articulated connection [between AMTK 7303] was twisted and fractured. All rolling assembly attachments [guidance bars] were broken. The rolling assembly of AMTK 7504 detached during the derailment.

Figure 36. AMTK 7504 Supported end and left side.

The suspended end wall exhibited indications of car to car impact although the structure was not compromised, the articulated connection [between AMTK 7424] was fractured. The lower retention straps were broken. Both guidance bars were deformed and fractured.

1.5.2.5.7 AMTK 7424 Coach

The right-side wall of AMTK 7424 was severely compromised. From the suspended end, about 30% of the side wall was sheared from the side sill and roof line. The roof was split and opened from the suspended end to the approximate center of the car. Four of five passenger windows were missing. The entire right side of the car was scraped deformed and heavily abraded. The right side of the car exhibited an orange paint transfer consistent with paint from an orange container on the back of a truck trailer that was involved in the highway collisions with the cars.

The right-side roof/side also exhibited signs of rubber transfer and white paint transfer consistent with engagement with the semi-truck.

Figure 37. AMTK 7424 Suspended end and left side.

The left side wall of AMTK 7424 was heavily scraped and abraded but remained intact. The structure was slightly pushed inward from the suspended end to the approximate center of the car. The roof line from the suspended to the approximate center of the car end was fractured and slightly pushed inward. Four of five windows were missing.

Figure 38. AMTK 7424 Left side.

The supported end of AMTK 7424 exhibited indications of car to car engagement. The right-side tower support structure was deformed, deflected downward and partially separated from the end wall. Both air springs were in place during this examination. The weight bearer connections failed. The articulated connection [between AMTK 7424] was fractured during the derailment. All rolling assembly attachments [guidance bars] were broken. The rolling assembly of AMTK 7424 detached during the derailment and rolled across Interstate 5.

Figure 39. AMTK 7424 supported end.

The end wall on suspended end of AMTK 7424 completely separated from the end frame. The structure exhibited signs of car to car impacts on the right side. The articulated connection [between AMTK 7423] fractured during the derailment. The weight bearer bars were fractured at the base. Both lower guidance bars were overstressed and fractured.

Figure 40. AMTK 7424 suspended end.

1.5.2.5.8 AMTK 7423 Coach

The right-side wall exhibited a gouge 74-inches long, 12-inches tall, and 20-inches deep in the area near the side passenger door. At this location the interior floor rose approximately 12-inches resulting in a small loss of occupied space. One side passenger window was not in place during this examination apparently removed during the passenger evacuation.

Figure 41. AMTK 7423 Right side.

The left side wall was relatively undamaged. One side passenger widow was not in place during this examination; apparently removed during the passenger evacuation.

The upper left tower support on the supported end was deformed upward. Both air springs remained in place. The supported end weight bearer bars were bent and fractured consistent with a vertical lifting motion. Their attachments to the supported end remained intact. The main safety cables for the rolling assembly were both broken. The upper horizontal safety straps for the rolling assembly were broken. The rolling assembly partially detached during the derailment. The exposed end of the rolling assembly collided with AMTK 7421. (See section 1.4.1.1, Sequential Kinematic Interactions.) The guidance bars were observed to have been torch cut. The articulated connection [between AMTK 7424] fractured during the derailment.

The suspended end wall on the left side was compressed and exhibited indications of car to car engagement. The articulated connection [between AMTK 7422] fractured during the derailment. The weight bearer connection appeared to have been torch cut the base. The lower guidance bars were overstressed and fractured. No straps were present during this examination. The left strap attachment hook was missing, the right was in place.

1.5.2.5.9 AMTK 7422 Coach

The right side of AMTK 7422 was relatively undamaged. The leading end of the right side-wall was deformed and peeled rearward. Immediately behind this damage was an impact deformation measuring about 2-feet wide and 16-inches deep. All windows were in place during this examination.

The left side wall of AMTK 7422 was scraped and abraded along the full length of the car. The side wall was deformed inward near the side passenger door and the structure was compromised below the passenger windows at a location 12-feet from the supported end of the car. All passenger windows were in place; one window was shattered.

Figure 42. AMTK 7422 Left side.

The supported end tower supports were severely deformed and sheared from the end wall. The end wall showed indications of car to car contact. The weight bearer bar mounts failed on both sides. Both primary rolling assembly retention cables, upper and lower safety straps were broken. The upper guidance bars were deformed, overstressed and fractured. The rolling assembly from AMTK 7422 detached during the derailment. (The rolling assembly was located adjacent and partially inside 7504,) The articulated connection [between AMTK 7423] fractured during the derailment.

Figure 43. AMTK 7422 Supported end.

The suspended end of AMTK 7422 exhibited indications of car to car engagement. The end wall was not structurally compromised. The right-side weight bearer bar was deformed and bent exhibiting indications it sheared from the car it was connected to (AMTK 7421). The left side weight bearer bar fractured at its base. The articulated connection (between AMTK 7421) fractured during the derailment. The lower truck retention straps were not present. The right-side strap mount was separated from the end wall. The lower guidance bars were overstressed and fractured.

1.5.2.5.10 AMTK 7421 Coach

The right side of AMTK 7421 exhibited several indications of impacts to the side wall of the car. Two of the impacts compromised the structure. One was located below the passenger windows about 12-feet from the supported end of the car. The damaged measured about 3-feet in length and 2-feet high. The maximum depth of the damage was measured to be about 12-inches. The other impact that compromised the side wall structure was about 30-feet from the supported end above the passenger windows. The damage measured about 12-feet in length and 2-feet high. This damage was consistent with the resting position of the car after the derailment wherein the left wheel of the rolling assembly from AMTK 7423 collided with the side wall of AMTK 7421. All passenger windows were in place, two were shattered, one was punctured.

Figure 44. AMTK 7421 Right side.

The left side of AMTK 7421 was relatively undamaged. The side wall was damaged near the supported end and investigators noted there was orange paint transfer consistent with paint from an orange container on the back of a truck trailer that was involved in the highway collisions with the cars. All passenger windows were in place and undamaged except one passenger window on the left side. It appeared to have been removed because of the evacuation.

The suspended end wall of AMTK 7421 exhibited indications of car to car impact. The right-side tower support was deformed downward and separated from the end wall structure. Both weight bearer bar mounts were overloaded and sheared. All rolling assembly retention cables and straps were broken. The upper guidance bars were overloaded and fractured. The rolling assembly of AMTK 7421 became detached during the derailment. The articulated connection [between AMTK 7422] fractured during the derailment.

Bridge railing structure is evident in figure 45 at the lower left adjacent to the articulated coupler.

Figure 45. AMTK 7421 Supported end.

The suspended end wall of AMTK 7421 exhibited indications of car to car engagement. The left side weight bearer bar was present, sheared from the mounting point of AMTK 7420. The right-side weight bearer fractured at its base. The articulated connection [between AMTK 7420] fractured during the derailment, although the cars remained in line with each other when they came to rest. The right lower rolling assembly retention strap was broken, the left was not present during the examination. Both lower guidance arms were overloaded and sheared.

1.5.2.5.11 AMTK 7420 Coach

The right-side wall structure of AMTK 7420 was relatively undamaged. The structure exhibited no indications of compromise. All passenger windows were undamaged. One passenger window was removed. [Emergency exit window]

The left side wall structure was relatively undamaged. The leading end left side exhibited some signs of collision engagement however, the damage was minimal. All passenger windows were in place and undamaged.

The left side weight bearer bar mounting point was overloaded and sheared. The right-side mounting point remined intact but the bar was fractured at its end. The articulated connection was fractured between AMTK 7421.

The rolling assembly of AMTK 7420 remained attached during the derailment. The left main rolling assembly retaining cable broke. All other rolling assembly retention straps and cable were intact. The right side upper guidance bar remained in place the left was deformed slightly but intact. The left side lower guidance bar was overloaded and fractured at the opposing car connection point (AMTK 7421). The lower left guidance bar appeared to have fractured at the bell crank.

Figure 46. AMTK 7420 Supported end and right side.

The suspended end wall of AMTK 7420 exhibited indication of car to car engagement. The articulated connection of AMTK 7420 remained intact with AMTK 7102 during the derailment. The weight bearer bars appeared to be straight, the connections were torch cut. The articulated connection was torch cut. The lower guidance bars appeared to have been torch cut. The lower truck retention straps were not present during this examination.

1.5.2.5.12 AMTK 7102 Baggage Car

AMTK 7104 was relatively undamaged. The rolling assemblies [the baggage car is designed with two rolling assemblies] remained in place. After the derailment this car remained upright and connected to its leading car, AMTK 7420 and the trailing locomotive, AMTK 181.

Two lower rolling assembly retention straps were present during the examination, they were both broken.

1.5.2.5.13 AMTK 181 GE P-42 Locomotive

AMTK 181 did not derail and was undamaged.

1.5.2.6 Survival Factors

This section of the report focuses on the issues related to the survivability of the passengers and the train crew that was traveling in the passenger cars, and the ability of the passengers and crew to safely evacuate the cars. In this section additional information regarding the passenger car interior design, safety features and exits are examined.

The exterior passenger door is 32-inches wide and when opened; automatic retractable steps extend to provide passengers with a means of stepping down from the train. These steps are located 16-inches above the top of the rail. Each service car is equipped with a hinged exterior access door for service personnel. This service door had an opening of 31 inches.

Each passenger car, the Bistro and Dining car is equipped with four emergency windows which can be accessed from the exterior by first responders or removed from the inside by passengers. These windows are comprised of double-paned laminated safety glass and marked for emergency egress. The remaining side windows are double paned laminated glass that cannot used for emergency egress. Window openings are about 53-inches wide and 29-inches tall.

The cars are equipped with an internal glass door fitted with tempered safety glass that is located at either end of the car. The door is electrically powered. When the electrical power is removed; 20 pounds of force is required to manually open the door. In addition, at each end of the car, a small hammer is provided for passengers to use to break the door glass in the event the door fails to open.

The coaches are equipped with nine rows of double seats on each side of the aisleway. The first three rows and last row of seats do not rotate. Tables are provided for the seats located at the one end of the car. The Business Class has eight rows of double seats on one side of the aisle and a single seat in the last row. In Business Class, the first and last row of seats do not rotate. On the opposite side of the aisleway, there are nine rows of single seats.

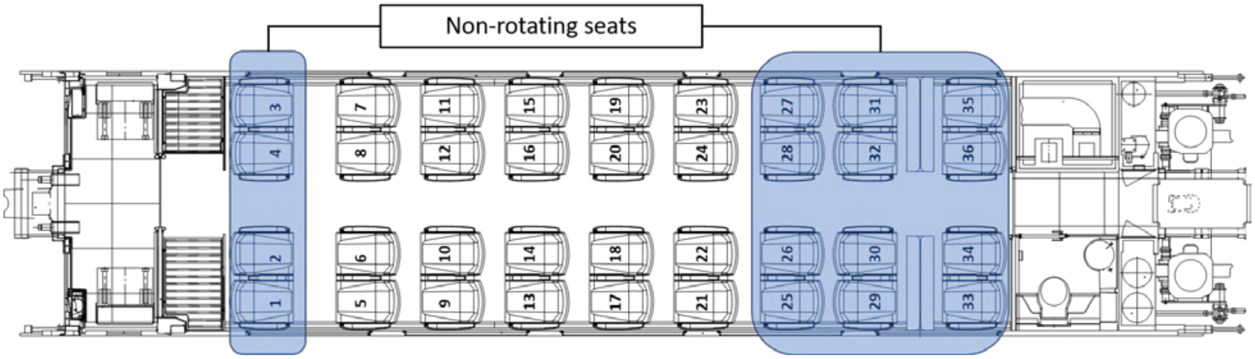

Figure 47. Talgo coach class seating layout.

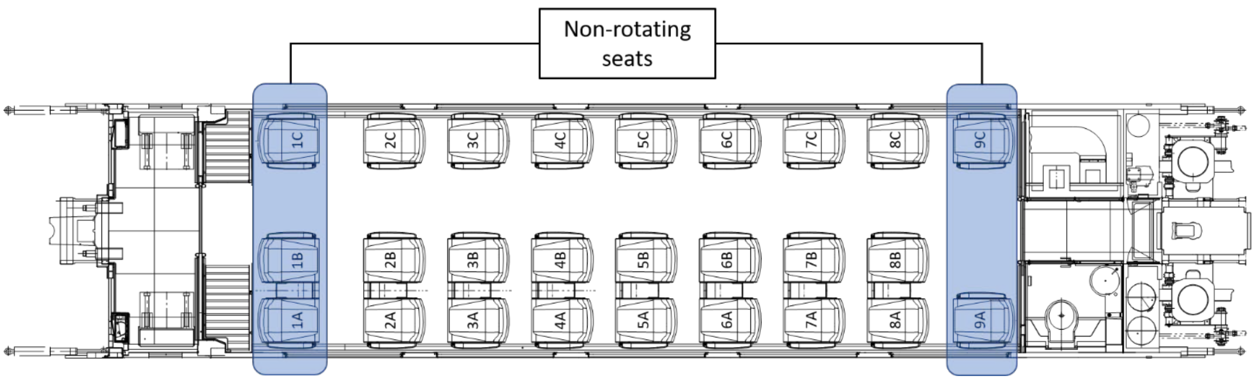

Figure 48. Talgo business class seating layout.

Both wheelchair accessible cars have a single seat with the adjacent space available for a wheelchair bound passenger, five rows of double seats and a single seat in the last row on one side of the aisleway. The other side of the aisleway has a space designated for a wheelchair bound passenger, and five rows of single seats. Wheelchair accessible cars have two wheelchair lifts mounted to the frame of the car adjacent to the two exterior loading doors. (See appendix 12, Photographs of passenger car interiors.)

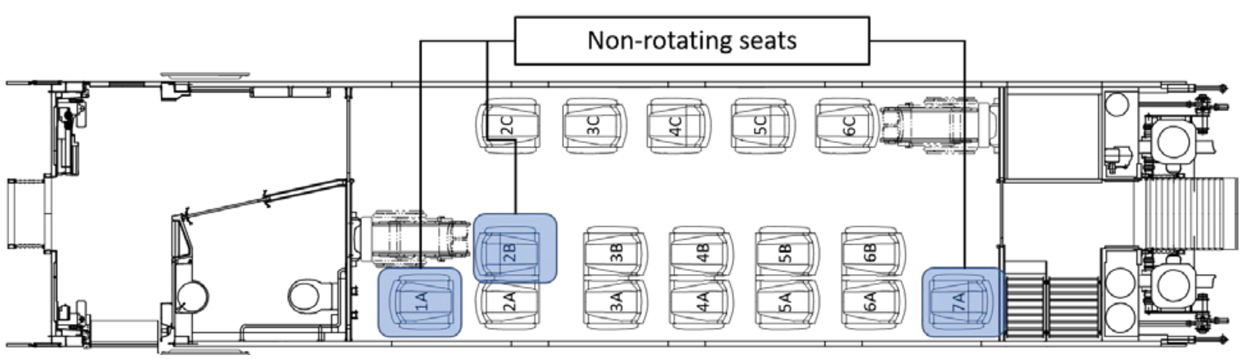

Figure 49. Coach class ADA layout.

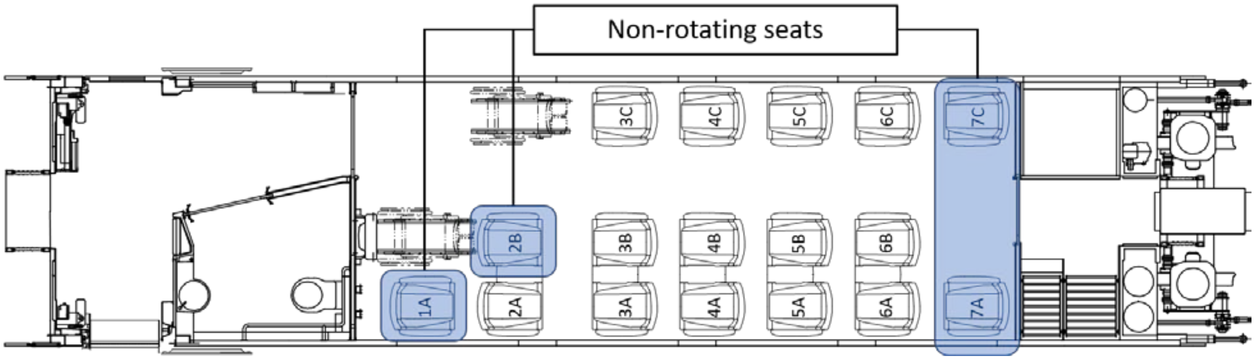

Figure 50. Business class ADA layout.

There are two non-revenue cars, a Dining Car and a Bistro Car. The Dining Car has a capacity for 30 diners. There are ten tables present in this car. Five of the tables will accommodate four diners and the remaining five accommodate two diners each. The Bistro car has a long counter type surface that permits seven passengers to sit on stools in a “bar-like” atmosphere. There are also two small tables located to the rear and opposite side of the car. The Bistro Car also incorporates a kitchen area with a large sink, multiple ovens and two work station tables.

1.5.2.6.1 Post-Accident Observations of Passenger Car Interiors

Investigators examined and assessed passenger interior damage resulting from the derailment with an emphasis placed on the loss of survivable occupant space and interior features that may have contributed to survivability within the car. The results of the observations are shown in Table 5. See attachment 12, Passenger Car Interior Damages.

Car	Interior Observations
AMTK 7454	Minor damage. Interior intact. No loss of survivable occupant space.
AMTK 7554	Right side wheelchair lift was partially detached from car structure. Minor damage to left side wheelchair lift. Seat 4C on left side of car at point of deformation rotated towards aisleway. Ceiling panels displaced and deformation above Seat 4C. Glass divider for overhead luggage bin broken and found on floor. Minor damage to seat components (trays and cushions). No loss of occupant space.
AMTK 7804	Right side interior ceiling collapsed. Right side tables and seats broken. Glass partitions between seating positions are broken on both sides of car. Seats shifted and deformed. Survivable occupant space present.

AMTK 7303	Significant amounts of dirt and debris found inside of car. Partial collapse of overhead ceiling. Front emergency window frame and car bowed inward on right side. Wall mounted cabinet and counter displaced. Extensive damage to seating area. Survivable occupant space available.
AMTK 7504	Extensive damage caused by separation of both wheelchair lifts from car body. Length of car shortened 4 feet, floor deformation at highest point 29.5 inches, roof collapse shortened height to 20 inches and compromised seats #17/18. Seat rotation, floor rise, and ceiling collapsed eliminated survival space except at seats #21, 22 and 25. 60% of seats lost to crushing.
AMTK 7424	Roof and luggage rack collapse reducing overhead space. Survival occupant space maintained at seats # 21 through 33.
AMTK 7423	Last three rows of double seats rotated due to deformation to lower right sidewall. Right rear emergency window smashed due to impact with seat occupant. Rear glass partition behind last row of seats right side broken. Survivable occupant space available.
AMTK 7422	Right side on fourth row, double seat (#21/22) rotated. No loss of survivable occupant space.
AMTK 7421	Table located on right side between first and second row of double seats broken due to penetration of car structure. Seat # 21/22 located four rows back on the right side found rotated. No effect on available occupant space.
AMTK 7420	Minor damage. No loss of survivable occupant space.

Table 5. Post-accident observations of passenger car interiors.

1.6 Injuries

As mentioned in section 1.5.1.5, Locomotive Survival Factors, the locomotive engineer sustained blunt impact trauma to the head, facial fractures from impact with the interior structures that collapsed due to the impact with the trees and a fractured right elbow from impact with the console. The qualifying conductor, who was riding in the locomotive cab, sustained injury to his lower extremities, back and spinal injuries and blunt impact trauma to his torso.

1.6.1 Passenger Cars

An assessment was conducted to the interior compartments based on the injuries sustained by the passengers and the damage to the cars. Information on the type and severity of passenger injury was based solely on information obtained through passenger interviews due to the inability to obtain medical records. At the time of this report (June 2018) the injury information is INCOMPLETE. Passengers provided their car and seat locations, an overview of the events that occurred in the passenger cars and basic injury description. This information is available in Attachment 13, Witness Interviews.

Table 6 shows the passenger injury information based only on those passengers that were interviewed, not medical records. Investigators could not verify precisely the classification of the injuries therefore the information represents injured or not injured based on statements from passengers. (Except for the fatalities.)Ten passengers were either fully or partially ejected from the train during the derailment. Of the 81 occupants present in the passenger cars; this includes three members of the Amtrak crew; 57 individuals were injured.

Car Number	Passengers	Fatal	injured	Not Injured	Ejection	Partial ejection
AMTK 7454	3	0	3	0	0	0
AMTK 7554	6	0	5	1	0	0
AMTK 7804	3	0	3	0	0	0
AMTK 7303	2	0	1	1	0	0
AMTK 7504	9	3	5	1	2	2
AMTK 7424	11	0	10	1	5	0
AMTK 7423	6	0	6	0	0	0
AMTK 7422	8	0	1	7	0	0
AMTK 7421	22	0	18	4	0	1
AMTK 7420	2	0	2	0	0	0
Location unknown	4	0	3	1	0	0
Pending interviews	5	-	-	-	-	-

Totals	81	3	57	16	7	3

Table 6. Breakdown of passenger injuries. **[INFORMATION INCOMPLETE]**

1.6.2 Highway Vehicles

Southbound Interstate 5 in DuPont, Washington is a heavily traveled major arterial roadway that traverses the state of Washington north and south. It is the main thoroughfare between two of the state's largest cities, Seattle and Tacoma.

On the morning of the derailment, the sun had not yet risen. The derailing Amtrak train struck several highway vehicles after it departed the right of way entered the roadway. Additionally, parts of the train detached during the derailment and were involved in collisions with several vehicles on the interstate. In all, eight vehicles were damaged resulting either from the collision with the derailing train or from detached train components or debris. In addition to the eight vehicle operators, there were two passengers traveling in the involved vehicles. A total of eight vehicle occupants were injured.

1.6.2.1 Highway Vehicle Crash Sequence

At 7:33 a.m., a Freightliner tractor in combination with an intermodal trailer was traveling at 61 mph southbound on Interstate 5 as recorded by the truck's Electronic Logging Device (ELD). In his interview with investigators, the truck driver said he was in the "center" lane. The truck driver advised that 3-4 miles before the crash, the train while traveling on the track, passed him on his right. The truck driver reports that he observed the entire train pass his truck which was traveling approximately 61 miles per hour southbound on the interstate. As the truck driver approached the overpass, he said he observed AMTK 7424 entering the roadway north of the overpass and strike his trailer. The [train] car was already sliding on its roof when it entered the roadway. The impact from the car damaged the steel intermodal trailer and pushed the truck out of its original lane of travel. As the car was dragged along the side of the trailer, it slowed the Freightliner to 23 miles per hour.

The ELD recorded the time of the deceleration at 7:34 a.m. As the truck continued southward, passing under the overpass, it was struck by the Power Car, AMTK 7903 that had entered the roadway just south of the overpass. The Freightliner came to final rest near the right side of the roadway. The truck sustained heavy damage to the cab, windshield, the engine and the engine cowling. Because of the damage sustained by the truck cab, the driver's door became wedged and the truck driver was forced to climb out of the passenger window. The driver sustained minor injuries in the collision and required medical attention.

A Ford F-150 pick-up truck was damaged when AMTK 7454 entered the roadway south of the overpass in front of it. The driver reported that he was unable to stop and struck the car. AMTK 7424 collided with the rear of the truck as it slid to a stop on the interstate. The driver sustained severe injury as did the front-seat passenger, who was trapped in the vehicle and had to be extricated by the first responders.

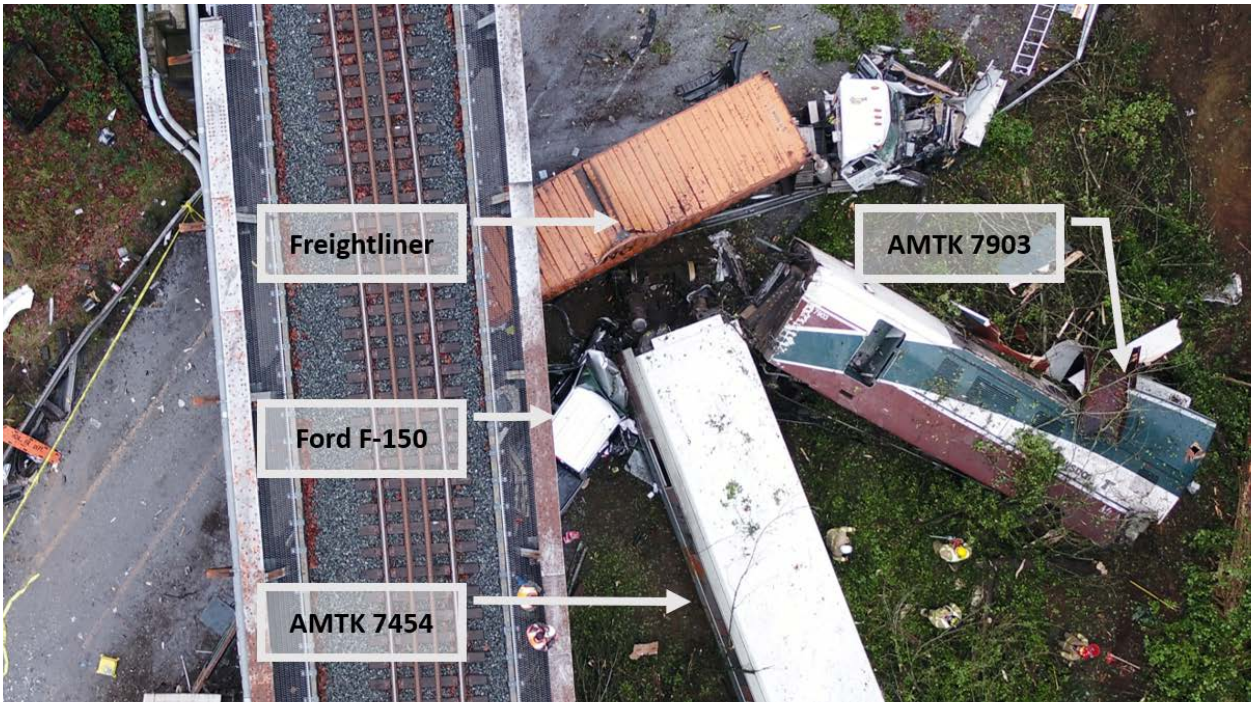

Figure 51. Final resting position of Ford F150 and Freightliner. (Photo WSP)

A white Toyota RAV4 was traveling south in the right lane when the driver reported seeing debris flying along the right side of the interstate. The driver advised that it was at that point that her vehicle was struck from behind. The driver lost control of the Toyota which spun out of control crossing all the southbound travel lanes of the interstate. The vehicle came to final rest on the left side of the roadway, facing north in the southbound lane. Subsequent investigation revealed that the Toyota RAV4 was struck from behind by the lead locomotive as it entered the roadway and slid to a stop on the interstate. The driver was treated for minor injuries at a local area hospital.

A green Kia Soul and the black Jeep Grand Cherokee were struck by the rolling assembly weighing approximately 4,500 pounds that had detached from AMTK 7424. The rolling assembly struck the front hood of the Kia and the rear of the Jeep; causing both drivers to lose control of their vehicles. Both vehicles sustained extensive crush damage resulting from the impact with the rolling assembly. The driver of the Kia was pinned inside of her vehicle when the engine block was shoved rearward, collapsing the dashboard and steering column onto her. The driver had to be extricated by first responders but sustained only minor injuries in the crash. After being struck by the rolling assembly, the Jeep rotated 180° striking the metal guard rail before coming to final rest. The Jeep occupant also received minor injuries in the crash.

Figure 52. Green Kia and rolling assembly on Interstate 5. (Photo WSP)

Figure 53. Damaged Jeep Grand Cherokee.

Figure 54. Detached rolling assembly and Jeep Grand Cherokee. (Photo WSP)

Vehicle	Damage	Occupants	Injured	Fatal	Serious	Minor
Ford F-150	Extensive	2	2	0	2	0
Freightliner tractor and trailer	Extensive	1	1	0	1	0
Kia Soul	Extensive	1	1	0	0	1
Jeep Grand Cherokee	Extensive	2	2	0	0	2
Kenworth tractor and trailer	Moderate	1	0	0	0	0
Nissan Altima	Moderate	1	1	0	0	1
Toyota RAV4	Extensive	1	1	0	0	1

Hyundai Santa Fe’	Moderate	1	0	0	0	0

Table 7. Highway vehicle injury breakdown. [Chart incomplete pending medical records.]

1.7 Occupant Space Design and Safety

1.7.1 Occupant Restraint

During this derailment, the passengers experienced both forward and lateral forces. Several passengers sustaining serious head and torso injuries during the derailment. Amtrak 501 is not equipped with “occupant restraint systems” utilized in other forms of passenger transportation such as seatbelts or airbags. These common forms of occupant restraint are found in the airline industry and in passenger vehicles but not in passenger trains. The primary strategy for occupant protection in passenger trains is “compartmentalization”. This strategy involves attempting to restrict the movement of the occupants in a railroad accident and thus limiting the potential for injury. During the secondary collision responses, the train occupants continue moving at the train’s initial speed while the train rapidly decelerates. A secondary impact occurs when an occupant collides with an interior surface, such as the seatback in the row ahead. An occupant may survive a collision with an interior surface (e.g., seat back, wall, or table) during an accident if the forces and accelerations are within acceptable human tolerance levels.

In one instance, a family boarded Amtrak 501 and sat in AMTK 7421. The family was traveling with an infant in a car seat. The parents reported that they were unaware that the train would not have securement straps necessary to belt the car seat into one of the seats in the car. Subsequently, the car seat containing the child was placed on top of a table during the journey. Just prior to the derailment; the father reported that he removed the child from the car seat and entered the lavatory. The car seat was left on top of the table. During the derailment, the unrestrained car seat was ejected out of AMTK 7421. The car seat was recovered outside near AMTK 7424 near a disconnected truck assembly.

Figure 55. Child car seat near AMTK 7424. (Photo FBI)

Amtrak's policy for the transportation of minors aboard their trains is that a child, under two years of age and riding for free, can utilize an available seat if it is not needed for a paying passenger. If no seat is available, the child is assumed to be carried on the lap of the paying adult. No safety provisions are made for smaller children, even if they pay for a seat. No additional restraint system is provided for vulnerable occupants; such as infants, smaller children or the elderly.

1.7.2 Passenger Ejections

During the derailment, AMTK 7424 detached from its leading and trailing car (AMTK 7504 and AMTK 7423) and struck the overpass concrete bridge abutment. The car rotated 180° and rotated over onto its roof before sliding to a stop on Interstate 5. During the accident sequence, the structural supports that held the windows in place buckled and several of the windows broke out or fell out. Five passengers inside of the car were ejected out of the car and were according to emergency responders, motorists and other passengers found lying on the Interstate.

As a result of the derailment, AMTK 7421 came to rest hanging from the overpass and resting on top of AMTK 7424. The de-coupling of AMTK 7421 from its lead car, AMTK 7422, left an opening at the lowest point of the car, where it had been previously coupled. A female passenger sitting near the front of that car was thrown from her seat and partially ejected through the opening.

Figure 56. AMTK 7421 resting on AMTK 7424. (Photo WSP)

Figure 57. Open end of AMTK 7421. (Photo WSP)

Two of the deceased passengers were ejected out of AMTK 7504 when the side wall of the car was breached by the rolling assembly belonging to AMTK 7422. The rolling assembly tore a hole into the underside of the car as it flipped over onto its right side during the derailment. The rolling assembly was found inside of the car. In addition, two more passengers were partially ejected out of the opening created by the car's structural breach. Another passenger was fatally injured when he was struck by the rolling assembly inside of the car.

In total there were seven full train passenger ejections and three partial ejections.

1.7.3 Passenger Seating

Some of the seats in the Talgo Series VI train are designed to rotate. (See figures 47-50) The release mechanism, located under the side of seat at the aisle, can be manipulated by a crewman by simply stepping on the latch. The row of seats can be rotated around and locked back into position. The rotation of the seats is accomplished by turning the seats starting at one end of the car and working to the other end. Once the seat has been rotated into place, the locking mechanism must be engaged to lock the seat into position and prevent inadvertent rotation.

Post-crash interviews revealed that several passengers in AMTK 7423 were injured when three rows of seats started to rotate. Seat numbers 1, 2, 5, 6, 9 and 10.

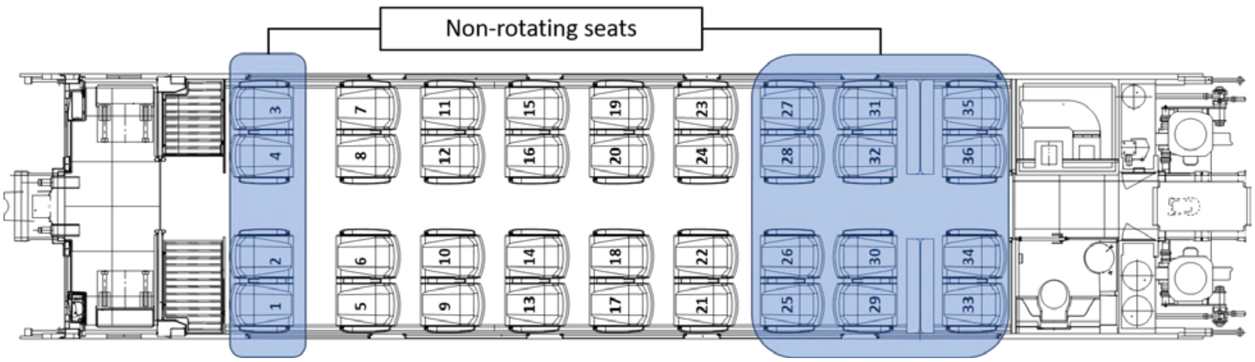

Figure 58. Coach class seating layout showing rotating and non-rotating seats.

One passenger was struck in the head with enough force that it threw her into the window which she shattered when her face contacted the window. The seat corner of seat 2, which is not designed to rotate, contacted the rear bulkhead of the car, shattering the glass partition, directly behind the seat. A post-crash examination of AMTK 7423 revealed that during the derailment; the metal railing on the southside walkway on the overpass penetrated the lower portion of the car's sidewall. This resulted in the displacement of the interior sidewall. The three rows of seats were displaced laterally causing the seats to rotate. Figure 59 shows the intrusion by the metal railing into the car. and shows the displacement of seats caused by the intrusion.

Figure 59. Bridge railing penetrating AMTK 7423 and displaced passenger seats.

A passenger in AMTK 7422 reported that a row of seats started to rotate during the derailment. This car sustained only minor exterior damage and no interior damage. The seats were identified as 21/22 and examined. The locking mechanism was found in working order and no obvious defects could be found. The locking mechanism appeared not to have been engaged. No passenger injuries were associated with the rotation of the seat in this car. Seats 1A and 1B (non-rotating type) were twisted from there normal positions and seat 4C had rotated in AMTK 7554. Although not engaged when investgators examined the mechanism from 4C, no defects were found.

1.7.4 Handicap Accessibility

Amtrak 501 was equipped with two handicap accessible cars. One was the Business class, AMTK 7554 and one was the Coach class, AMTK 7504. Two wheelchair lifts were provided in each car, one on each side of the car adjacent to the exterior door. In the stowed position, the lifts were secured by a metal pin that bolted the wheel chair assembly to the overhead frame of the lift and to the floor of the car. In AMTK 7554, the right-side wheelchair lift was found to be detached from its securement bracket on the floor and pulled away from the top by a force exerted on the bottom of the lift at the time of the derailment. The wheelchair lift was found partially attached, and hanging, obstructing access to the exterior door. On the left side of the car, the wheelchair lift was still in place. The lift had sustained damage and the securement latch had been bent but the lift was still functional. A closer inspection of the wheelchair lift assemblies revealed that the structural buckling of the car frame allowed the wheelchair lifts to detached from the floor. The weight of the wheelchair lift pulled the top of the lift away from the car structure.

Figure 60. Exemplar wheelchair lift and damaged lift in AMTK 7554.

A post-accident inspection of AMTK 7504 revealed that both wheelchair lifts were missing. Both had been forcibly pulled away from their securement bracket attached to the end of the car. The right-side lift, after detaching from the car structure, was propelled through the interior of the car and breached the exterior wall of the lavatory. After detaching from the car's structural support, the left side wheelchair lift was propelled to the right and towards the opposite door at the end of the car.

Only one-wheel chair lift was recovered from the scene. Components from the second lift were recovered. Due to the extensive damage to the car and to the recovered wheelchair lift, it was not possible to determine which wheelchair lift had been recovered from the debris. Figure 61 shows the interior damage to AMTK 7504 and the location where the wheelchair lifts were mounted prior to being torn away from the car structure. Figure 62 shows the damage resulting from the right-side wheel chair lift being propelled into the exterior lavatory wall in the car.

Figure 61. Photograph of missing wheelchair lift and damage to AMTK 7504.

Figure 62. Photograph of the interior lavatory damage of AMTK 7504.

1.7.5 Interior Glass

The Talgo Series VI cars are equipped with internal glass door fitted with tempered safety glass at the end of each car that separates the vestibule from the interior of the passenger compartment. The doors slide into place on a runner behind or in front of the last row of seats in each car. The door is electrically powered. When the electrical power is removed; 20 pounds of force is required to manually open the door. A glass partition is also located at one end of each car. A small utility hammer is provided for passengers to use to break the glass door in the event of an emergency. The sign notifying passengers of the present of the hammer and the intended use is not photo luminescent and would not be visible in low or no-light conditions.

Investigators noted the vestibule door in AMTK 7422 was jammed during post-accident interior examinations. Reasonable attempts were made by investigators to open the door, but it did not move. The utility hammer remained in place.

Figure 63. Jammed vestibule door, AMTK 7422.

Despite being fitted with safety glass, several of these doors shattered during the derailment. In AMTK 7421, the door shattered just behind two seated passengers in the front row of the car. In addition to the glass interior doors, glass partitions are also incorporated into seating interior design for the Dining and Bistro cars. These partitions are used to separate seating positions and are located directly behind the head of the passenger. Several of these partitions shattered during the derailment. Glass is also used in the composition of the ornate seat design.

In the overhead luggage bin area, glass dividers are used to partition the space. Several broken dividers were found on the floor of the cars during the post-crash inspection.

1.8 Emergency Egress and Signage

1.8.1 Emergency Lighting and Public-Address System

Current requirements for passenger car emergency lighting are outlined in Title 49 CFR, 238.115, Emergency Lighting. The final rule for Emergency lighting was established in November 2013.

238.115 (a) (1-4) requires equipment ordered after 2000 or placed in service for the first time after 2002 to have batteries for emergency lighting that can withstand 8g – 4g – 4g and orientation of 45° however this equipment was built before 2000. The Talgo trainset is required to comply with 238.115 (b)(1-2) that states the equipment should comply with APTA standard PR-E-S-013-99, Rev. 1 "Standard for Emergency Lighting System Design for Passenger Cars" that requires cars to have emergency lighting, "powered from either the main battery system, or independent power source(s). Each emergency light fixture shall activate automatically or be energized continuously for the duration specified in Table 1, whenever the car is in passenger service and normal lighting is not available."

The final rule stipulates that no later than December 31, 2015, at least 70 percent of each railroad's passenger cars that were ordered prior to September 8, 2000, and placed in service prior to September 9, 2002, be in compliance with the emergency lighting requirements.

In December 2015, Amtrak petitioned the FRA seeking a temporary waiver of compliance for the emergency lighting requirements until December of 2017. The justification was based on the fact that 70 percent of Amtrak's fleet was placed into service prior to 2002, thus needing modification. In April of 2016, FRA denied the request in the interest of public safety.

According to passengers and emergency responders, the separation of the cars resulted in the loss of lighting that hampered both the passengers' ability to evacuate from the train and the first responders rescue operation. In this Talgo train, the batteries are in the power car in the front of the train and the baggage car in the rear of the train. Auxiliary batteries are not provided for the individual cars.

After the derailment, most passengers self-extricated. The inability of the crew to communicate with the passengers resulted in the passengers having to decide on their own initiative whether to evacuate and to determine the safest route of evacuation. Most of the passengers reported that they had no contact with the crew after the derailment. The Public Address (PA) System, which is available on the train, would not have been operational because the train came apart in this derailment.

This system is a normally hard-wired system which is dependent on the train's electrical system and not wi-fi based. Once the cars detached, the entire train lost both power and signal for the PA system.

Current requirements for passenger car markings and instructions for emergency egress and rescue access are outlined in Title 49, *CFR* Part 238.125, Marking and Instructions for Emergency Egress and Rescue Access. The rule states that, on or after January 28, 2015, emergency signage and markings shall be provided for each passenger car in accordance with the minimum requirements specified in APTA PR-PS-S-002-98, Rev. 3, "Standard for Emergency Signage for Egress/Access of Passenger Rail Equipment," Authorized October 7, 2007, or an alternative standard providing at least an equivalent level of safety, if approved by FRA pursuant to § 238.21.

Specifically, the rule enhances requirements related to the use of high performance photoluminescent (HPPL) material, i.e., a photoluminescent material that is capable of emitting light at a very high rate and for an extended period of time, as well as policies and procedures for ensuring proper placement and testing of photoluminescent materials. These revisions are intended to help ensure greater visibility of signage and markings in an emergency situation so that train occupants can identify emergency exits and the path to the nearest exit in conditions of limited visibility, which include, but are not limited to conditions when all lighting fails, or when smoke is present in the passenger car.

Existing emergency egress signage inside some passenger compartment areas within passenger cars has been ineffective due to its inability to absorb sufficient levels of ambient or electrical light. The requirements in this rule improve the conspicuity of signage and markings in the passenger compartment, and thus increase the discernibility of the exit signs and markings.

Approximately two years before the derailment, Amtrak performed an internal audit of its inventory for compliance with federal regulations. At that time, Amtrak identified several problems with their fleet in general and the Talgo train sets specifically. During testing for emergency lighting requirements, Amtrak discovered that the signage in the Talgo cars lacked the required photo luminesce for instructional signs for the operation of emergency door, emergency exit signs, instructional signs for doors and windows. Amtrak also noted that the Talgo train sets did not comply with the federal regulations regarding emergency lighting in the car aisles and passageways during low-light and no-light operations. Amtrak presented its findings to the local Talgo representative.

Talgo reported to investigators that there is a project underway on the Talgo Series VI trainsets to:

- Replace the emergency door opening instruction signs with ones compliant with the current HPPL requirement
- Replace the retroreflective border around the manual release levers and handles with compliant HPPL material
- Increase the illumination in the vestibule to assure the above material is sufficiently charged.

As of this writing, the expected completion date is August 2018.

The additional work to upgrade the emergency lighting to bring it into compliance is scheduled to be completed in the Talgo Series VI cars by the spring 2019.

1.8.2 Emergency Doors

1.8.2.1 Signage

The instructions to operate the door are located on the bulkhead above the manual release lever. It provides a four step; step by step instruction, to the passenger on how to open the door to evacuate the train. Because the process to open the doors is not intuitive, instructions are required to be placarded.

The instructions advise the user to:

> *Press a green button (some signs indicate to wait 5 seconds before going to next step). When the main or auxiliary power is available, the door will usually slide open which alleviates the need to proceed further with the instructions.*

(In the event that the door fails to open), Pull the red lever. It is made to operate in the either up or down position.

Pull up on handle. The handle releases the mechanism that is holding the door in place.

Pictorial and instructions to use two hands to push out and sideways to slide the door open.

During the post-crash inspection of the cars, all the placards were found to be in place.

However, none of the placards possess any photo luminesce which means that in low or no-light situations, the signs cannot be seen by passengers attempting to use the door for egress in an emergency.

1.8.2.2 Door Operation

At the end of each car in the vestibule area are two exterior doors that provide emergency egress. During normal train operation (under power), the train's electrical system releases the door and allows the door to be opened. Under emergency power, the train's electrical system still provides some electrical power to operate the door. In the event, that the door doesn't automatically open, the electrical system can provide some assistance to allow the ease of opening the door manually.

During the loss of all electrical power; to include emergency auxiliary power, the door operation is manual only. A loss of the electrical power assist can occur whenever the cars become detached such as in a crash or derailment. The exterior door is of substantial weight and even some adults will have difficulty pushing the door open.

During the post-accident inspection, several undamaged doors were selected at random and opened. Whereas all the doors could be opened; several issues did arise. In one instance, the red lever only worked in the up position; though it was designed to work by either pulling down or pushing up to release the manual pull handle. Talgo committed to revising their maintenance procedure to assure both directions will perform as intended.

Another issue found with the lever involved the wire ties Talgo used to secure the lever to prevent accidental or deliberate tampering. In one case, the wire tie increased the difficulty in actuating the lever. Investigators had to use both hands and lean against the handle with their full weight to break the wire and move the lever.

It should be noted, that when investigators examined an exemplar undamaged trainset on March 7, 2018, at the maintenance facility in Seattle, Washington, similar issues with the tampering device hampering door use were found when trying to operate the door release mechanism. The issue was communicated to Amtrak and Talgo who committed to look at possible improvement. Talgo advised investigators they are researching alternatives.

In AMTK 7423, two passengers reported that they had attempted to exit the train after the derailment but could not get either of the exterior doors to open. An examination of the rail car revealed that whereas evidence was present to indicate that someone had attempted to open the door; it was clear that not all the proper steps to open the door were performed. The instructional placard was present but did not possess the required photo luminesce by regulation. The derailment occurred prior to sun up.

Figure 64. Exemplar emergency door showing instruction placard.

1.8.3 Emergency Windows

Several undamaged windows were found both inside and outside of the cars. Window zip strips were also found inside of several cars indicating that the emergency windows were used for egress after the derailment.

The exterior windows on each car had been marked with a decal indicating the proper way to use the window in an emergency. The car windows were found to function as designed. However, several of the passengers, bystanders and members of the fire department reported that the multiple window markings were confusing. The instruction provided to gain access through one window was not the same as the instructions provided to gain access to the adjacent window. In several instances, individuals were attempting to gain access through a window incorrectly, delaying access to the interior of the car and the rescue effort.

Figure 65 illustrates the decals found on the exterior of the rail car near windows on the Talgo cars. Instructions to correctly gain access are for the side passenger windows only. Figure 65 also shows the instructions for the emergency windows located at the first and last windows on each side of the cars.

Figure 65. Exterior emergency window removal instructions.

1.9 Damages Estimates

The information in the table below was provided by Amtrak.

Equipment	Ownership	Disposition	Damage estimate
WDTX 1402	State of Washington	Total loss	$7,237,000.00
AMTK 7903	State of Washington	Total loss	$2,712,000.00
AMTK 7454	State of Washington	Total loss	$1,298,000.00
AMTK 7554	State of Washington	Total loss	$1,298,000.00
AMTK 7804	State of Washington	Total loss	$2,005,000.00
AMTK 7303	Amtrak	Total loss	$2,005,000.00
AMTK 7504	State of Washington	Total loss	$1,298,000.00
AMTK 7424	State of Washington	Total loss	$1,298,000.00
AMTK 7423	State of Washington	Total loss	$1,298,000.00
AMTK 7422	State of Washington	Total loss	$1,298,000.00
AMTK 7421	State of Washington	Total loss	$1,298,000.00
AMTK 7420	State of Washington	Total loss	$1,298,000.00
AMTK 7102	State of Washington	Total loss	$1,062,000.00
AMTK 181	Amtrak	Undamaged	$0.00
TOTAL			$25,405,000.00

Table 8. Amtrak train 501 damage estimate.

1.10 Tests and Research

A selection of intact safety straps from the accident train set and from an exemplar train set were retained by the NTSB Materials Laboratory for further examination and mechanical testing. Tests to determine the tensile breaking strength for each of the submitted straps were completed. Results of the testing, documented in Materials Laboratory Factual Report 18-042, showed the straps fractured at loads that were approximately 10% to 50% of the breaking strength of 38,500 pounds force (design load of 5,512 pounds force with a safety factor of 7). Full results of the testing are documented in Materials Laboratory Factual Report 18-042.

1.11 Post-Accident Actions

Group participants may draft information for this section that would show any post-accident follow up actions that would be relevant to the overall facts of this investigation. As an example, Amtrak/Talgo could elaborate of the strap replacement witness when we visited in March 2018.

2 Attachments

1. Federal Register / Vol. 64, No. 91 / Wednesday, May 12, 1999 / Rules and Regulations Passenger Equipment Safety Standards
2. Federal Register/Vol. 78, No. 230 /Friday, November 29, 2013/Rules and Regulations Passenger Train Emergency Systems II
3. Amtrak’s Initial Petition for Grandfathering Talgo Series VI Passenger Railcars Static End Strength Requirements October 18, 1999
4. United States Department of Transportation Federal Railroad Administration Transcript of Public Hearing for the Petitioning of Grandfathering Non-Compliant Equipment July 21, 2000
5. United States Department of Transportation Federal Railroad Administration Grandfathering of Non-Compliant Equipment for Use on Specified Rail Lines Initial Decision September 8, 2000
6. Summary Report: Crashworthiness Evaluation of Amtrak’s Talgo Series VI Train June 14, 2001

7. Report to Volpe National Transportation Systems from Author D. Little, Inc. Crashworthiness Evaluation of Amtrak’s Talgo Series VI Train February 2002
8. Amtrak’s Petition for Permanent Grandfathering Talgo Series VI Passenger Railcars Static End Strength Requirements February 2002
9. United States Department of Transportation Federal Railroad Administration Grandfathering of Non-Compliant Equipment for Use on Specified Rail Lines Final Decision March 27, 2000
10. American Public Transportation Association Standard for the Design and Construction of Passenger Railroad Rolling Stock SS-C&S-034-99, Rev. 2 Originally Approved October 14, 1999, Revision June 2006
11. U.S. Rail Equipment Crashworthiness Standards, David C. Tyrell, Volpe National Transportation Systems Center, U.S. Department of Transportation, May 2001
12. Photographs of Passenger Car Interiors
13. Witness Interviews
14. Materials Laboratory Factual Report 18-042